HEALTH SCIENCE AND PHYSIOLOGY

For Tropical Schools

By

F. DANIEL

Oxford University Press

Oxford University Press
BOMBAY CALCUTTA MADRAS KARACHI KUALA LUMPUR
CAPE TOWN IBADAN NAIROBI ACCRA

First published 1953
Reprinted 1953, 1954 (with corrections),
1954, 1955, 1958

PREFACE

This book is primarily designed for use in the upper classes of secondary schools in tropical and sub-tropical countries. Its main aim is to provide a substantial foundation of accurate knowledge that will enable the student to understand the principles that govern healthy living in tropical conditions, so that after he leaves school he may be equipped to play an active and responsible part in promoting the health and well-being of his family and community.

My smaller volume on *Health Science for Tropical Schools* (Oxford University Press) was intended for use by students following the course of General Science covered by my four text-books on *General Science for Tropical Schools* and deriving the necessary background of pure science and physiology from that source. But there is now a need (particularly in schools that do not teach General Science) for a more extensive and self-contained text-book of Health Science such as that provided by the present volume, which follows the syllabus in Health Science introduced by the University of Cambridge Local Examinations Syndicate for their Oversea School Certificate.

I am grateful to the Oxford University Press for permission to use material from my earlier volume. In revising and extending this material for the present book I have received much help from Dr. Charles Wilcocks's *Health and Disease in the Tropics* (Oxford University Press, 1950), which I strongly recommend to teachers of Health Science. Many of the illustrations by Dr. Wilcocks and by Mr. J. H. Grundy have been reproduced here with their kind permission.

F. DANIEL

CONTENTS

INTRODUCTION: HEALTHY LIVING 1

1. YOUR BODY AND HOW IT WORKS 3

The human animal: the body-regions of a mammal, an outline of how higher animals live. Digestion: the food-canal. Getting oxygen—breathing: the lungs, examination of lungs. The transport of food and oxygen in the body: the vascular system, the lung circulation, the body circulation. The blood: red blood-cells, white blood-cells, tissue fluid and lymph. Excretion. Cells and tissues: tissues, organs, systems of organs. The skeleton: the skull, the backbone or spinal column, the ribs, the limbs. Muscles and their action. The skin. The nervous system: the nerves, reflex action, voluntary action, the central nervous system.

2. FOOD AND NUTRITION 45

The classification of foods: carbohydrates, complex sugars, simple sugars, complex carbohydrates, fats, proteins, mineral salts, water, vitamins. Food and energy: energy output and food requirements, body-weight and food requirements, energy values of food, diet planning, requirements of mineral salts. Vitamins: vitamin A—its sources and effects, vitamin B_1, nicotinic acid—the pellagra-preventing vitamin, riboflavin—vitamin B_2, vitamin C—ascorbic acid, vitamin D—calciferol. Protective foods. Some important foodstuffs: milk, eggs, fish, legumes, green leafy vegetables and fruits, sugar. Cooking: food hygiene. Metabolism: ingestion, digestion, digestion in the mouth, digestion in the stomach, digestion in the small intestine, the final products of digestion, absorption, diffusion and dialysis, assimilation and the functions of the liver.

HYGIENE OF THE ALIMENTARY SYSTEM 87

Disorders of the digestive system. Parasites of the food-canal:

intestinal worms, round-worms, thread-worms and whip-worms, hook-worms, tape-worms, guinea-worms. Intestinal diseases: dysentery, typhoid fever, cholera, appendicitis.

4. THE RELEASE OF ENERGY DURING RESPIRATION . . 99

Internal respiration. Body-temperature: control of body-temperature.

5. THE NERVOUS SYSTEM 104

The sense-organs: the eye, examination of eye, the ear, experiments on hearing, sense of balance and position, internal sense organs, senses of taste and smell, feeling, touch, temperature and pain. Chemical control: hormones, another type of chemical control. Instinct and intelligence.

6. THE SKELETON AND MOVEMENT 118

Muscle action. Teeth: diseases of the teeth, prevention of dental disease, dental inspection.

7. HYGIENE OF THE SKELETAL, MUSCULAR, AND NERVOUS SYSTEMS 128

Bone injuries—fractures. Value of muscular exercise. Fatigue, rest, sleep. Hygiene of the nervous system. Hygiene of the sense-organs: hygiene of the eyes, hygiene of the ears, hygiene of the organs of taste, smell, and touch.

8. HYGIENE OF THE RESPIRATORY SYSTEM 137

The importance of fresh, clean air: ventilation, the cooling effect of ventilation. Diseases which enter the body through the air-passages: droplet infection, diphtheria, measles, whooping-cough, smallpox, chicken-pox, tuberculosis and consumption, sore throat, the common cold, influenza.

9. HYGIENE OF THE BLOOD SYSTEM 151

The heart: examination of heart. Arteries. Veins. The clotting of blood. Hygiene of the blood system: the importance of muscular exercise. Fainting and shock. Wounds and bleeding. Pus-forming bacteria—blood-poisoning, tetanus—lockjaw, snake-bite, rabies—hydrophobia. Diseases carried by blood-sucking insects. Mosquitoes: external features, life history of mosquito. Malaria: life-history of malaria parasite, the prevention of malaria.

Mosquito control: protection against mosquito-bites, destruction of malaria parasites. Yellow fever. Filaria worms. Dengue and sand-fly fevers. Kala azar. Plague. Typhus. Leptospirosis. Bilharzia. Sleeping sickness—trypanosomiasis. Relapsing fever.

10. HYGIENE OF THE SKIN 190

Skin diseases: scabies, yaws, leprosy, lice, bed-bugs, chiggers. Ulcers.

11. REPRODUCTION 199

12. THE CONQUEST OF DISEASE 201

Bacteria: everyday importance of bacteria. Food preservation. Prevention of bacterial disease: disinfection, disinfecting-agents, natural disinfecting-agents, physical disinfecting-agents, chemical disinfectants.

3. PUBLIC HEALTH SERVICES 211

Water supply: large-scale purification of water. The disposal of wastes: the disposal of human excreta, pit latrines, bore-hole latrines, bucket latrines, septic tanks, water-carriage sewerage systems. Refuse disposal. Housing. Food purity. Control of infectious diseases. Registration of births and deaths: vital statistics. Infant welfare and school medical services. Public health education.

APPENDIXES

A. FOOD TABLES 231

B. PRACTICAL WORK 243

On dissection: food and digestion: sense-organs: respiration.

C. ELEMENTARY CHEMISTRY AND PHYSICS APPLIED TO HEALTH SCIENCE 263

Burning and breathing: composition of atmosphere: air pressure: measurement of temperature and heat energy: water-vapour in the atmosphere.

D. EFFECTS OF ALCOHOL 280

GLOSSARY 281

NDEX 297

ACKNOWLEDGEMENTS

Thanks are due for permission to reproduce illustrations from the following sources:

BIBBY: *An Active Human Biology* (Messrs. William Heinemann Ltd.), *Figs.* 8, 15, 17, 18, 19, 20, 40, 52, 64. CAMPBELL: *Those Teeth of Yours* (Messrs. William Heinemann [Medical Books] Ltd.), *Figs.* 53, 55. HOLMES and GIBBS: *A Modern Biology*, *Figs.* 5, 35, 48, 59; *Journal of Hygiene, Plague Supplement III, January* 1914, *Fig.* 74 (both published by the Cambridge University Press). CULLIS and BOND: *The Body and its Health*, *Figs.* 12, 13, 41 (Messrs. George Allen & Unwin Ltd.). STRASBURGER: *A Textbook of Botany* (Messrs. Macmillan & Co. Ltd.), *Fig.* 16 (*a*). DAKIN: *The Elements of General Zoology*, *Figs.* 16 (*b*) and (*c*), 63, 83; HATFIELD: *An Introduction to Biology*, *Figs.* 16 (*d*), 23, 30, 47; YAPP: *Animal Physiology*, *Fig.* 34; BISHOP and LOCKET: *An Elementary Chemistry*, *Fig.* 39; FREWIN: *A New Experimental Science*, Book I, *Fig.* 110 (all published by the Clarendon Press). BORRADAILE: *Elementary Zoology for Medical Students*, *Fig.* 49; CUNNINGHAM: *A Text-book of Anatomy*, *Fig.* 54; THOMSON: *Outline of Zoology*, *Fig.* 66 (Oxford Medical Publications). *Nouveau Petit Larousse Illustré* (Librairie Larousse, Paris), *Fig.* 24. MANSON-BAHR: *Tropical Diseases*, *Fig.* 26; WELLS, HUXLEY and WELLS: *The Science of Life*, *Figs.* 32, 38 (both published by Messrs. Cassell & Company Ltd.). PLIMMER and PLIMMER: *Food, Health and Vitamins*, *Fig.* 27; DAVIES: *Hygiene and Health Education*, *Fig.* 56 (both published by Messrs. Longmans, Green & Co. Ltd.). ROAF: *A Text-book of Physiology*, *Figs.* 29, 42, 45, 46; DRUMMOND: *Introduction to School Hygiene*, *Fig.* 57 (both published by Messrs. Edward Arnold & Co.). STRACHAN: *Lessons in Elementary Tropical Hygiene* (Constable & Co. Ltd.), *Fig.* 33. DARLING and MURPHY: *Elementary Hygiene for Nurses* (Messrs. J. & A. Churchill Ltd.), *Figs.* 36, 81, 85. THOMSON: *Biology for Everyman* (Messrs. J. M. Dent & Sons Ltd.), *Fig.* 50. MURRAY: *Science Fights Death* (Messrs. Watts & Co.), *Fig.* 65. MINETT and SEVERN: *Practical Tropical Sanitation* (Messrs. Baillière, Tindall and Cox Ltd.), *Figs.* 96, 97. CLIFFORD and MOTTRAM: *Properties of Food* (University of London Press), *Fig.* 98.

Thanks are also due to the following:—

Dr. Charles Wilcocks and Mr. J. H. Grundy for allowing the use of the following illustrations from *Health and Disease in the Tropics* (Oxford University Press), —*Figs.* 69, 71, 72, 73, 75, 79, 70, 76, 77, 78, 80, 86, 87, 88, 89, 93, 94, 95. Of these, the first six were drawn by Mr. Grundy, the remainder by Dr. Wilcocks.

Burroughs Wellcome & Co. (The Wellcome Foundation Ltd.) for permission to reproduce *Figs*. 37, 60, 61.

The British Museum (Natural History) for permission to reproduce *Figs*. 67 and 68 from *A Mosquito Summary* by the late DR. J. F. MARSHALL.

The Controller, Her Majesty's Stationery Office, for permission to quote from *Tables of Representative Values of Foods commonly used in Tropical Countries* by B. S. PLATT, and to reproduce *Figs*. 1, 21, 22B, 51 from *Principles of Anatomy and Physiology for Physical Training Instructors* and *Fig*. 82 from *The Army Manual of Hygiene and Sanitation* (1934).

The Thresh Disinfector Co. for permission to reproduce *Fig*. 84.

Messrs. Wallace and Tiernan Ltd. for permission to reproduce *Fig*. 91

The charts on pages 59, 72, and 234–5 are re-drawn from *Nutrition*, published by the Department of Food, Government of India, New Delhi.

INTRODUCTION

HEALTHY LIVING

The aim of this book is to help with a very important part of your education for *life* (and not merely to help you to pass a written examination), since you cannot make full use of your life either as an individual or as a member of your community if you do not enjoy *full health.* As you will learn in this book, many different but closely-related activities are going on all the time in your body. When all these life-processes are going on smoothly and properly 'in step' with each other and with the external conditions around you, then your body is said to be *healthy*; but if this natural and normal condition of full health is disturbed, e.g. when something goes wrong with one of the essential living-processes, then you become *ill*, *sick*, or *diseased.* This unnatural and abnormal condition of ill-health, sickness, or disease may be caused (*a*) *by unhealthy surroundings*, or (*b*) *by unhealthy habits*, or (*c*) *by insufficient or unsuitable food*, or (*d*) *by harmful organisms that may enter the body.*

In this text-book of Health Science (or Hygiene) we shall consider the conditions which affect our health, so that we may learn to *control* these conditions and so *prevent* ill health and disease and the unhappiness they cause. *Prevention is better than cure*, and hygiene is sometimes described as the science of *preventive* medicine, since its aim is to *prevent* disease and thus avoid having to *cure* it.

Civilized countries have a *medical and health service*, usually organized by the State, and in some countries this service is divided into two main branches: (*a*) a *health* service, mainly concerned with *preventing* ill-health and disease, and (*b*) a *medical* service, mainly concerned with *curing* disease. Some progressive countries have, in addition, *social services*, designed to help in raising the general standard of health and happiness. In most such countries, the medical department was the first to develop, because when there was a shortage of properly trained medical men they could only find time to attend to the people whose need was most urgent, i.e. the people who were so unwell that they could not carry on their ordinary daily activities. But it was soon realized that most of this serious illness could be *prevented* if proper precautions were taken by individuals and by the community. In the past, some countries have spent enormous sums of money in providing very extensive hospital systems, only to find that this vast expenditure on *curing* disease in no way reduced the death-rate or the sickness-rate until a *preventive* health service was organized in addition. So specially trained health officers, trained in *preventive* as well as curative medical science, were organized into health services.

It is important to realize the difference between these two aspects of the battle against disease. If you allow your health to get so bad that you have to go to a doctor (or even enter a hospital) for *curative* treatment, your part in the healing process becomes largely *passive*, since most of the active treatment is carried out by doctors and nurses. But in the *preventive* work of the health service the individual and the community are *active* partners in the work, for the health officers, with their expert assistants, cannot do all the work themselves; they can only guide and encourage *YOUR* personal and communal efforts. In fact, the public health services can only succeed with willing and intelligent co-operation given by educated citizens who know the broad facts and understand the reasons that underlie the science of preventive medicine. The main object of this book, therefore, is to enable *YOU*, both as an individual and as a member of your community, to give this willing and intelligent co-operation and to play an *active* and responsible part in keeping yourself, your family, and your community in full health, learning the importance of healthy habits and proper food instead of putting your trust in bottles of medicine. To do this, you must have clear ideas about the following subjects: (*a*) The causes of ill-health and disease, (*b*) how the individual and the community can be protected from these harmful causes, and (*c*) the kind of living conditions needed to maintain full health.

Full health should be a natural and unconscious state of mind and body. John Locke (1632–1704), the great English philosopher, in his opening remarks to *Some Thoughts concerning Education*, wrote, 'A sound mind in a sound body is a short but full description of a happy state in the world. He that has these two has little more to wish for: and he that lacks either of them will be but little the better for anything else.'

CHAPTER 1

YOUR BODY AND HOW IT WORKS

Before you can understand the basic facts concerning health and disease you must have a clear, though elementary, idea of the structure and working of the human body under normal, healthy conditions.

THE HUMAN ANIMAL

From the scientific point of view, Man is an *animal*, with a body built on the same general plan as all the other members of that great class of animals called *mammals*, and when we come to study the internal structure of the human body it will often be helpful to examine the corresponding parts in a dissection of one of the smaller mammals.

The mammals form a large group of animals, including most of the common four-footed animals of everyday life, e.g. dogs and cats, rats and mice, horses and cows, sheep and goats, monkeys and men. There are also a few mammals that live in water—whales, porpoises, seals—and bats, which can fly. All the mammals have in common that their young are fed with milk by the mother-animal, which has *mammary glands* for this purpose. Most mammals also have other characteristics, e.g. (*a*) The skin is hairy; (*b*) They have external ears; (*c*) They grow more or less permanent teeth, sunk in sockets in the jaw-bones (these teeth being of different kinds, suitable for cutting, tearing, and grinding food); (*d*) They are 'warm-blooded', i.e. they can keep their inner body-temperature always the same, whether their surroundings are hot or cold; (*e*) They have a *diaphragm* dividing the body-cavity into two smaller cavities, one containing the four-chambered heart and the lungs, the other containing most of the organs concerned with digestion of food, reproduction and excretion of urine.

In nearly all mammals, the young ones grow from an egg while still inside the mother-animal, and the young are fairly fully developed when they pass out from the mother's body at birth, e.g. calves. Some are at first blind and helpless, e.g. new-born kittens, while others are able to look after themselves very soon after birth. The human baby is the most helpless of all young mammals and needs years of *parental care*. We can classify mammals in another way—according to the food they eat. A very large number are *herbivorous* or *plant-eating animals*; many of these live in herds when in the wild state and depend on their running-powers to escape from their enemies. Some other mammals are *carnivorous* or *flesh-eating animals*; these are hunters, living on the flesh of smaller or weaker animals. A few mammals, like Man, are *omnivorous*, feeding on both plants and animals.

Man is a mammal of a special kind. With the monkeys and the apes he forms a sub-group called the *primates*, mammals with large brains, useful, grasping hands, and clear-seeing eyes. Man is distinguished from other mammals by his upright position when walking and by his very large brain, but he has the same fundamental needs and his body works in much the same way as any other 'higher' animal. So we can learn a lot about Man by observing other mammals, e.g. by dissecting a rabbit or a rat as described on pp. 243–8 we can get a very good idea of what we ourselves are like inside.

The body-regions of a mammal

There are four distinct body-regions in most mammals: (i) the head, (ii) the neck, (iii) the trunk, and (iv) the tail. The neck is not clearly marked off, however, in whales and seals, mammals that live in water. The tail, also, is sometimes very short as in rabbits and bears, or almost absent as in guinea-pigs and men.

The Head. The head carries the animal's most important *sense-organs* (eyes, ears, and nose). In fact, the head is that part of the body which explores the unknown and puts the animal in touch with its surroundings. The head is clearly the best place for the sense-organs and for the mouth—on that part of the body which usually goes in front.

The Neck. The neck joins the head to the trunk. It enables the animal to turn its head without turning the rest of its body. (An animal without a neck, e.g. a frog, has to turn its whole body in order to look in a new direction.)

The Trunk. This forms the largest part of the body. In mammals, it is divided into two parts: (*a*) the *thorax*, or chest, surrounded by the *ribs* and *diaphragm* and containing the *lungs* and *heart*; and (*b*) the *abdomen*, or belly-cavity, enclosed in which are most of the body-parts concerned with digestion of food, with reproduction and with excretion of urine.

The Tail. In some mammals, e.g. kangaroos, mice, and some monkeys, the tail is used for balancing or for climbing; but in other mammals, e.g.

Man, it is very short and may not even project from the surface of the body.

The Limbs. There are two pairs of limbs attached to the trunk: (*a*) a pair of *fore-limbs*, and (*b*) a pair of *hind-limbs*. The limbs are used as jointed levers to enable the animal to move about.

An outline of how higher animals live

The first need of any animal is a sufficient supply of suitable food, which is used partly in building and repairing its body, partly as a source of energy. For during the growth of the animal and the formation of the complex chemical substances of which it is made, in movement and in keeping warm, the animal uses *energy*. A living thing cannot *create* energy, but it can change energy from one form to another. Living things can, like machines, be looked upon as *energy-transformers*. Green plants get energy, in the first place, from the sun, the *chlorophyll* (or *leaf-green*) absorbing that part of sunlight which supplies the energy necessary for *photo-synthesis*. During photo-synthesis, the green plant changes this light energy into *chemical energy*, stored up in the form of manufactured food. Animals cannot make this food themselves (they cannot photo-synthesize), but they get their food from plants or from other animals which have fed on plants. *All the energy used by living things, then, comes in the first place from the sun, and the important difference between animals and plants is that animals cannot transform the energy of sunlight into chemical energy.*

One of the most striking things about animals and plants is the way in which they are fitted or adapted to the surroundings in which they live (i.e. their *environment*). For instance, a green plant gets its food (including water) from the soil and the air, and we find that it is firmly rooted in the soil and exposes its leaves to air and sunlight. On the other hand, animals eat solid foods of various kinds and they drink liquids; so they have compact bodies. In finding their food they use *sense-organs*, and most higher animals move towards their food, using the pull of *muscles* on the jointed bones of their limbs, which act as levers. (The framework of *bones*, the *skeleton*, also serves to protect certain parts of the body.)

An animal is also adapted to deal with the food which it eats, both in its structure (the way it is made) and in its physiology (the way it works). The food is taken, through the mouth, into the *food-canal* (or *alimentary canal*). A good deal of the food eaten is not soluble in water, but once inside the food-canal it is broken down, or *digested*, into simpler, soluble substances, which can move easily through the walls of the food-canal into the *vascular system*. The *blood*, which fills this system, carries the dissolved food material round the body to the parts where it is used. Some of the food is used in building up new parts or in repairing worn parts of the body, but much of it is *oxidized* in the process of *respiration* and the energy thus set free is used in movement and growth, or it appears as heat.

The higher animal requires air, from which it obtains the oxygen used in respiration. Many aquatic animals, e.g. fishes, use the oxygen dissolved in the water in which they live. The higher animals mostly live in air and are covered with a skin, often hairy, through which oxygen cannot easily pass. An adaptation to land life is here seen in the possession of *lungs*, a breathing system and an oxygen-transporting system. The mammal takes air into its lungs (inside the chest), and from these the oxygen is carried by the blood to those places where oxidation goes on. The blood also carries the waste substances produced by the body; one of these, carbon dioxide, is lost through the lungs, others leave the body in solution by way of the *kidneys*, while a good deal of water escapes through the skin as *sweat*.

It is clear, then, that in the body of a higher animal many different things are taking place at the same time. If the body-machine is to work smoothly, all these activities—muscle movements, digestion of food, and transport of food materials, oxygen and waste products—must be kept exactly in step with each other. These processes are delicately controlled by the brain and the *nerves*, and by *hormones*. The special *sense-organs*, e.g. eye and ear, keep the animal informed of what is happening around it.

This briefly summarizes how the body-machine of the higher animal works, but there is one point more that applies to all living things. An animal's body cannot go on working for ever; sooner or later it 'wears out' and death takes place. Animals (like plants), however, have the power of *reproduction*, and before they themselves die, they usually bring into existence a new generation.

DIGESTION

The striking difference in the structure and appearance of plants and animals reflects the fundamental difference between their methods of feeding. Plant food is present almost everywhere—carbon dioxide is in the air; and water containing dissolved mineral salts is in the soil. A plant, therefore, does not need to move about from place to place in search of food (although it may have to search for sufficient light). A typical plant is fixed to one spot and develops as large a feeding surface as possible on thin, flat leaves, exposed to air and sun by the spreading branches, and on roots running through the surrounding soil in all directions. The typical animal is built on a more compact plan because it has to find its food ready-made and because it is not surrounded by suitable food, as a plant is.

Having found its food, an animal eats it and it is passed from the mouth into the *food-canal.* Here the solid food is *digested,* i.e. broken down into simpler substances that are capable of *diffusing* through a thin skin or membrane into the blood-stream.

The food-canal

Animal food must contain *carbohydrates, fats, proteins, water, mineral salts,* and *vitamins,* and we shall learn more about these in Chapter 2. For the present, it will be sufficient to know a few common examples of each group.

The commonest carbohydrates used for food are *starch* and *sugar*; rice, potatoes, and wheat-flour are starchy foods. Common sources of *fat* are meat-fat, butter, milk, egg-yolk, nuts, and vegetable oils. Protein is supplied by lean meat, white-of-egg, milk, and seeds (especially peas, beans, and lentils). You should also remember that *although carbohydrates, fats, and proteins can all be used to supply the animal with energy, only proteins can be used for body-building, i.e. for growth, repair, and reproduction.*

Man, like other mammals, takes in food at the mouth, with the aid of the lips and teeth. If the solid food is too large to go in the mouth, smaller pieces are bitten off by the front, or cutting, teeth. This food is then *chewed,* i.e. ground up by the back teeth and worked into a ball ready for swallowing. While the teeth are tearing and grinding the food, it is moistened and softened by the *saliva,* a digestive juice, which is poured into the mouth from the *salivary glands.* In Man, two pairs of these lie between the tongue and the lower jaw while a third pair lies to the outside of the lower jaw-bone just below the ear. (This is the gland that becomes infected and swollen when we get *mumps.*) The saliva contains an *enzyme* (see p. 79) which helps to break down *starch* in the food into soluble sugars. Thus digestion begins in the mouth. The food is swallowed, i.e. passed down the *gullet* (or *oesophagus*), which leads down inside the animal's neck and through the chest cavity to the *stomach* (see Fig. 1).

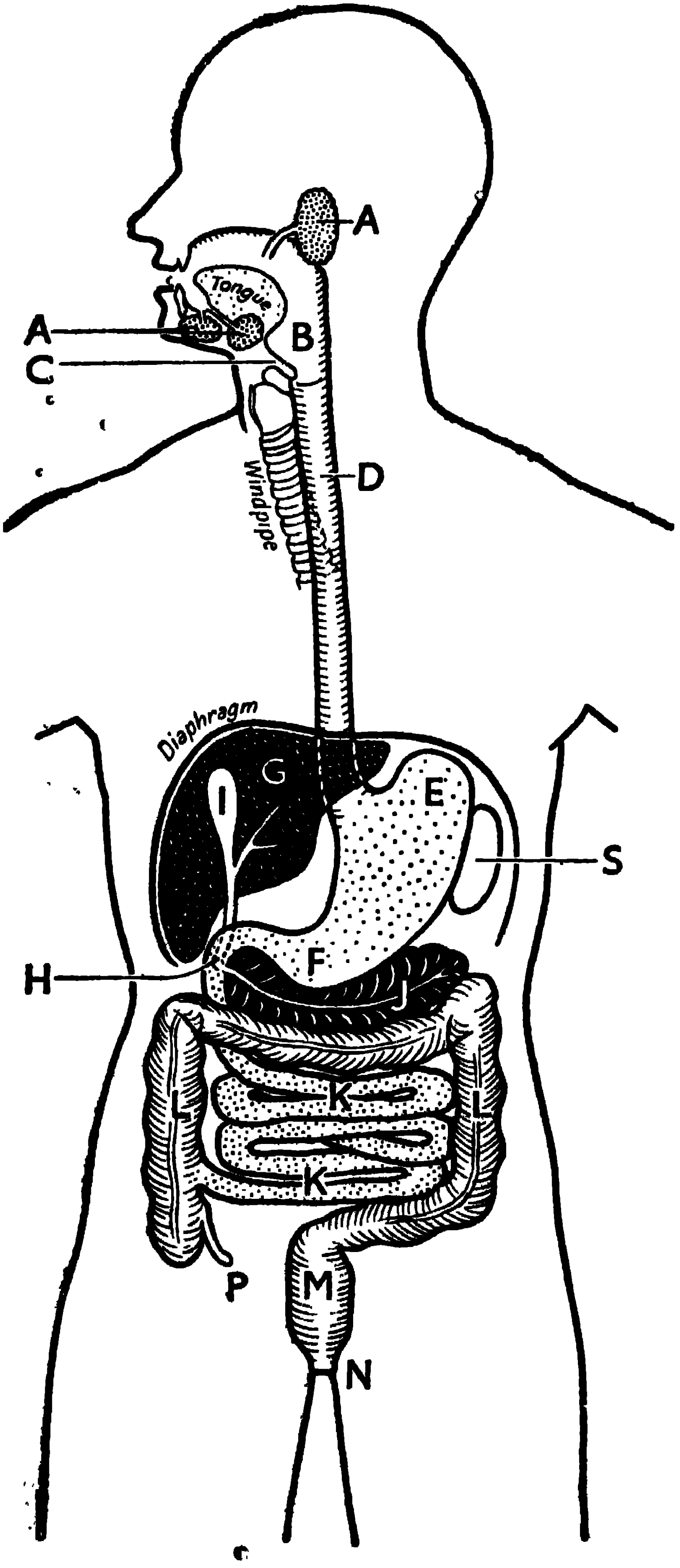


FIG. 1.—The Digestive System (diagrammatic)

A—Salivary glands. B—Throat (pharynx). C—Epiglottis. D—Gullet (oesophagus). E—Upper end of stomach. F—Pylorus. G—Part of liver. H—Bile and pancreatic ducts. I—Gall bladder. J—Pancreas. K—Small intestine. L—Large intestine. M—Rectum. N—Canal to anus. P—Appendix. S—Spleen (not concerned with digestion).

The *wind-pipe*, leading to the lungs, also opens into the back of the mouth, near the upper end of the gullet, and if food gets into the wind-pipe through this opening (the *glottis*), it is likely to cause choking. Such an accident is rare, partly because, during swallowing, the muscles at the top of the wind-pipe close the tube, partly because a small flap-like projection, the *epiglottis*, directs food away from the glottis during swallowing (see Fig. 2).

As soon as food is inside the gullet, it passes beyond *conscious* control. It does not, however, *fall* down the gullet, but is forced down by a series of muscular movements in the walls of the tube. Thus it is possible for animals (e.g. cattle) to eat with the head below the rest of the body. The muscles of the gullet contract behind and relax in front of the food-ball and thus push it quickly down into the stomach. These *involuntary* movements of the wall of the food-canal are known as *peristalsis* (see Fig. 32).

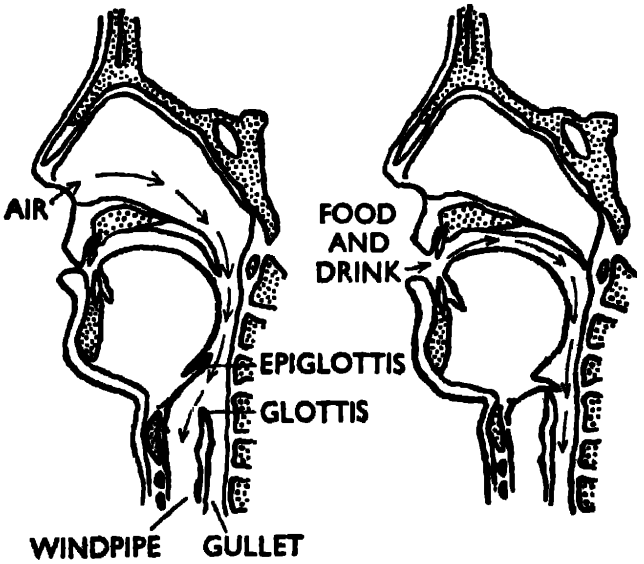


FIG. 2.—Breathing and swallowing

The *stomach* is a large muscular bag (situated immediately below the *diaphragm*) which holds the food for some hours while a digestive juice (the *gastric juice*) acts on it. During this stage in digestion the walls of the stomach move in such a way as to mix its contents thoroughly with the gastric juice. Afterwards the partly digested contents are squirted, a little at a time, into the *small intestine*, a long, narrow tube folded into many loops. (In Man, the small intestine is about 20 ft. long, i.e. it is only 'small' in diameter and in comparison with the large intestine.) In the small intestine, the partly digested food meets two more digestive juices, *bile* (from the *liver*) and *pancreatic juice* (from the *pancreas*), which carry digestion a stage further. Digestion is completed by the *intestinal juice* (from the walls of the small intestine), so that the digestible portion of the original solid food is now changed into simpler soluble and diffusible substances. This digested food is *absorbed* by the walls of the small intestine and passed on to the blood in the tiny blood-vessels running through these intestinal walls.

From the small intestine, the unabsorbed remains of the original food pass on to the *large intestine* in a very liquid state, and in this part of the food-canal water is absorbed, so that the waste material is reduced to about one-tenth of its former volume. It then passes through the *rectum* to the *anus*, where it is got rid of as *faeces*. The food-canal, therefore, is a digestive tube running from the mouth to the anus, open to the external world at its two ends. The lower part of the food-canal (the intestines) is sometimes called the *gut*.

This is a broad outline of the process of digestion. Later we shall learn how digested and absorbed food gets to the parts of the body where it is used.

Note. When you examine a dissected mammal (p. 245), you will find that the various parts of the food-canal do not lie free in the body-cavity, but that they are suspended in folds of thin and more or less transparent membrane (called the *peritoneum*). This membrane lines the body-cavity and also extends over the food-canal, which is suspended in a fold of the peritoneum known as the *mesentery*. In the mesentery run the blood-vessels supplying the food-canal.

GETTING OXYGEN—BREATHING

On p. 5 we learnt that *all living things use energy* and that animals get the necessary energy from their food. This process, during which food is oxidized and its chemical energy transformed into useful forms, is called *respiration*. This process involves taking in oxygen and giving out carbon dioxide, and it goes on in all living things, though usually more rapidly in animals than in plants. In its full modern sense, *the scientific term 'respiration' means the whole process of transforming energy by breaking down complex chemical compounds into simpler ones possessing less chemical energy.* In mammals some of the energy is released as *heat*; the rest is used in growth, repair, and movement.

Respiration involves the use of oxygen. *Plants* expose a large surface to the air and exchanges of oxygen and carbon dioxide take place over nearly the whole surface of the plant. Gases pass in and out of the tiny openings (stomates and lenticels) very readily by diffusion and they enter or leave the living plant cells by the same process. In the 'higher' animals, on the other hand, the body is very compact (i.e. the surface area is small compared with the total volume of the animal) and there are no openings in the skin comparable to stomates. In Man and the other 'higher' animals, the exchange of oxygen and carbon dioxide with the air takes place in one region only—the *lungs*—and not over the whole surface of the body. The air in the lungs is constantly renewed by the process we call *breathing*—which is quite distinct from respiration proper. In mammals, breathing means the alternate taking-in of a quantity of air into the lungs and the pushing-out of a gas poorer in oxygen and richer in carbon dioxide.

THE LUNGS

In Man and other mammals, the two lungs are soft, spongy bodies (see Fig. 3), lying in cavities of the chest (the *pleural cavities*). These cavities are lined by a very thin membrane, a fold of which, in each cavity, surrounds the lung, which therefore lies in a double-walled sac. A very thin layer of fluid in these *pleural sacs* helps to protect the lungs from damage by friction. The *ribs* and muscles enclose the top and sides of the chest-cavity, while its floor is formed by the *diaphragm*, a curved sheet of tough fibre with muscle round the edge, which separates the chest-cavity from the rest of the body-cavity (see Fig. 3). In this way, the lungs are enclosed in an air-tight chamber, which they always fill completely during life, and whose only opening to the outside world is through the wind-pipe. (This fact becomes obvious during the dissection of a mammal; if a small

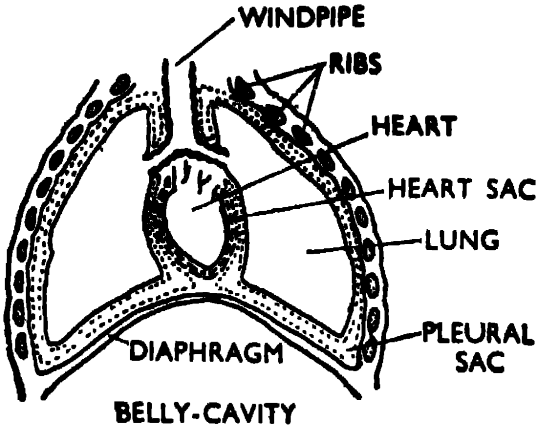


FIG. 3.—Diagram of Chest-cavity

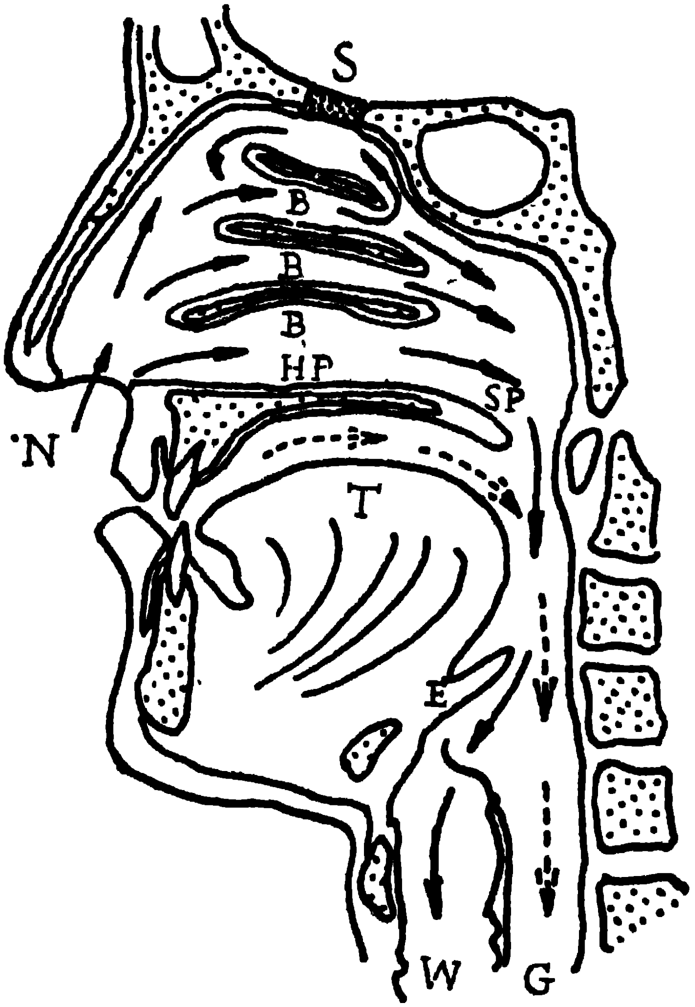


FIG. 4.—Vertical section through head

Dotted arrows show path of food and drink.
Black arrows show path of inspired air.
N: nostril. B: curved bones. S: sense-organ of smell.
HP: hard palate. SP: soft palate. T: tongue. W: wind-pipe. G: gullet.
E: epiglottis

hole is made into the pleural cavity, air enters this, the pressure inside and outside the lungs is equalized and, because the walls of the lungs are *elastic*, they now contract and the lung collapses.)

This observation should help you to understand the way in which you breathe. We say that, when we breathe, we 'suck' air into our lungs. Actually, the mechanism is very similar to that of a bicycle-pump. In order that air shall enter the lungs from the atmosphere, i.e. to breathe *in*, it is necessary to enlarge the volume of the chest-cavity and thus reduce the air-pressure inside the lungs (according to Boyle's Law). This is done by movements of the ribs and diaphragm. Some of the powerful muscles attached to the ribs contract and pull the ribs upwards and outwards, thus increasing the size of the chest-cavity all round. At the same time, the centre of the diaphragm is pulled downwards as the muscles around its margin contract, thus increasing the size of the chest-cavity still further. This increase in volume of the air-tight chest-cavity causes a reduced pressure inside the lungs, and *the air is forced down the wind-pipe by the pressure of the atmosphere outside*, until the air-pressure inside the lungs becomes the same as that of the outside atmosphere (see Fig: 8).

'Breathing-out' takes place when the muscles of the ribs and diaphragm relax and allow these parts to return to their original positions, thus forcing air out of the lungs through the wind-pipe.

In passing from the atmosphere into the lungs, the air first enters the *nostrils* (see Fig. 4) where it passes through a winding passage whose walls are covered with a sticky liquid. Under natural conditions, any dust or dirt is caught by this sticky liquid and by the hairs that grow in the entrance to the nose. At the same time, if the outside air is dry, it will become moistened with water-vapour as it passes through the nostrils, and there will be no danger of drying up the delicate absorbing area of the air-sacs in the lungs. Besides this, if the outside air is cold, it is warmed to about the same temperature as the blood when it travels through the

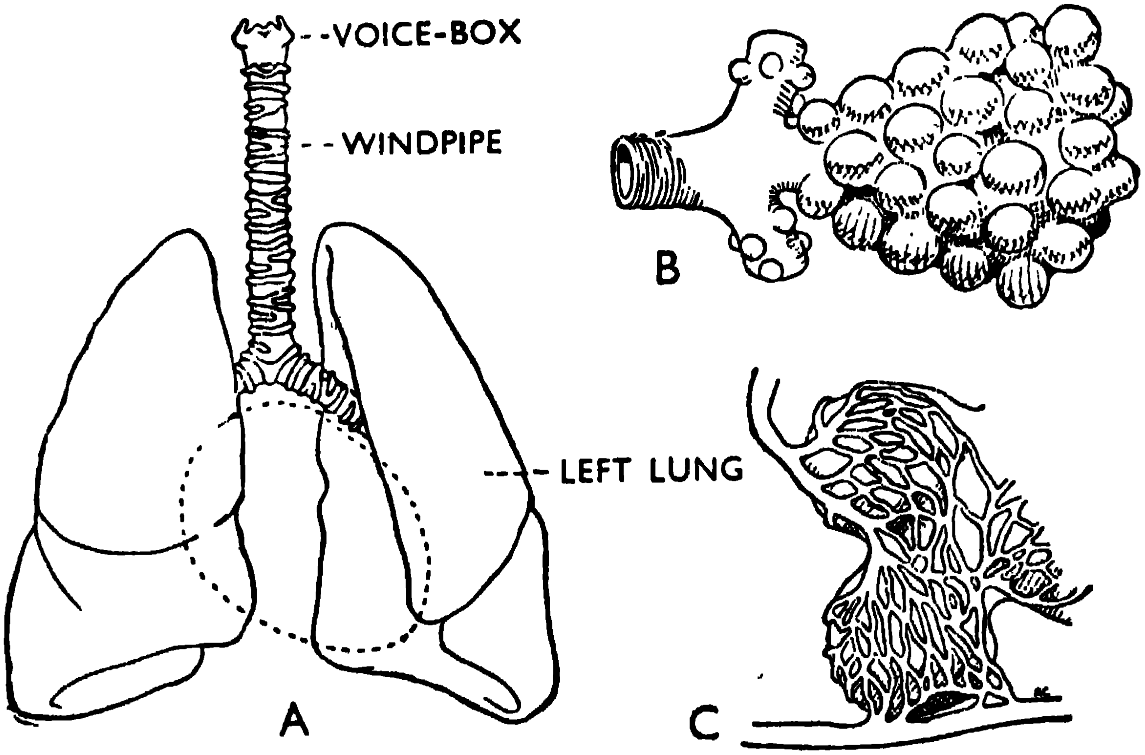


FIG. 5.—A: the lungs (dotted line shows position of heart). B: end of air-tube showing air-sacs (highly magnified). C: air-sacs surrounded by blood-capillaries (still more highly magnified)

winding passages in the nose, and this removes the danger of suddenly cooling the lungs. To sum up, *the air is filtered, moistened, and warmed in passing through the nose.* (*N.B.* The mouth has these safeguards less highly developed; hence 'mouth-breathing' is a bad practice.)

From the nose, the air passes down the back of the mouth-cavity into the *wind-pipe* (or *trachea*), which leads down through the neck into the lungs. The walls of the wind-pipe, too, are covered with a sticky liquid which is continually flowing towards the throat, carrying with it any dust which was not trapped in the nose.

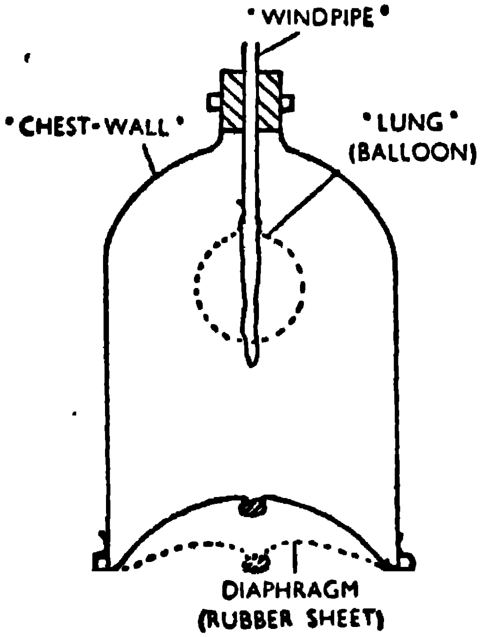


FIG. 6.—Model showing the action of the diaphragm in breathing

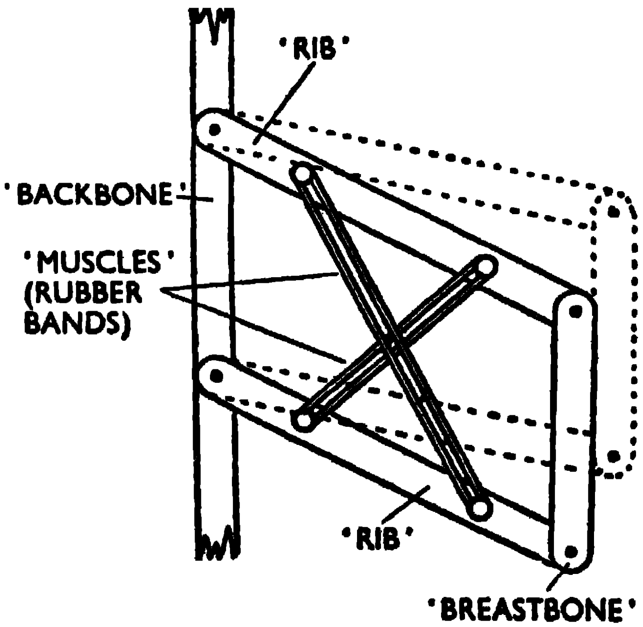


FIG. 7.—Model showing the action of the ribs in breathing

Inside the chest-cavity, the wind-pipe divides into two branches one leading to each lung, and these branch tubes divide again and again inside the lungs into still narrower air-tubes. These very fine air-tubes lead finally to tiny *air-sacs* (see Fig. 5), and it is here that the actual exchange of gases between blood and air takes place. The total area of all these tiny air-sacs is enormous: it has been estimated that if all the air-sacs in a man's lungs could be spread out flat, they would cover a total area of over 100 square yards, i.e. about a hundred times more than the area of his skin. Hence, although a mammal has a compact body with a relatively small surface area, the structure of the lungs provides, inside the chest-cavity, a very large surface across which oxygen is absorbed into the blood-stream.

The two models shown in Figs. 6 and 7 illustrate the way in which we breathe. (i) The bell-jar shown in Fig. 6 represents the chest-walls, and the rubber sheet tied across the mouth of the bell-jar represents the diaphragm. The rubber balloon represents a lung, and the glass tube represents the wind-pipe. On pulling down the 'diaphragm', the 'lung' fills with air. On pushing up the 'diaphragm', the 'lung' empties. This model, of course, only illustrates the action of the diaphragm during breathing, it does not show the part played by the ribs. (ii) The jointed framework shown in Fig. 7 represents two ribs attached to the backbone at their dorsal end and to the breastbone at their ventral end. The rubber bands represent some of the muscles between the ribs. As one set of 'muscles' contracts, the other set relaxes and the 'ribs' are lifted upwards and outwards; this enlarges the chest-cavity. When this muscle action is reversed, the 'ribs' and 'breastbone' return to their original positions (see also Fig. 8).

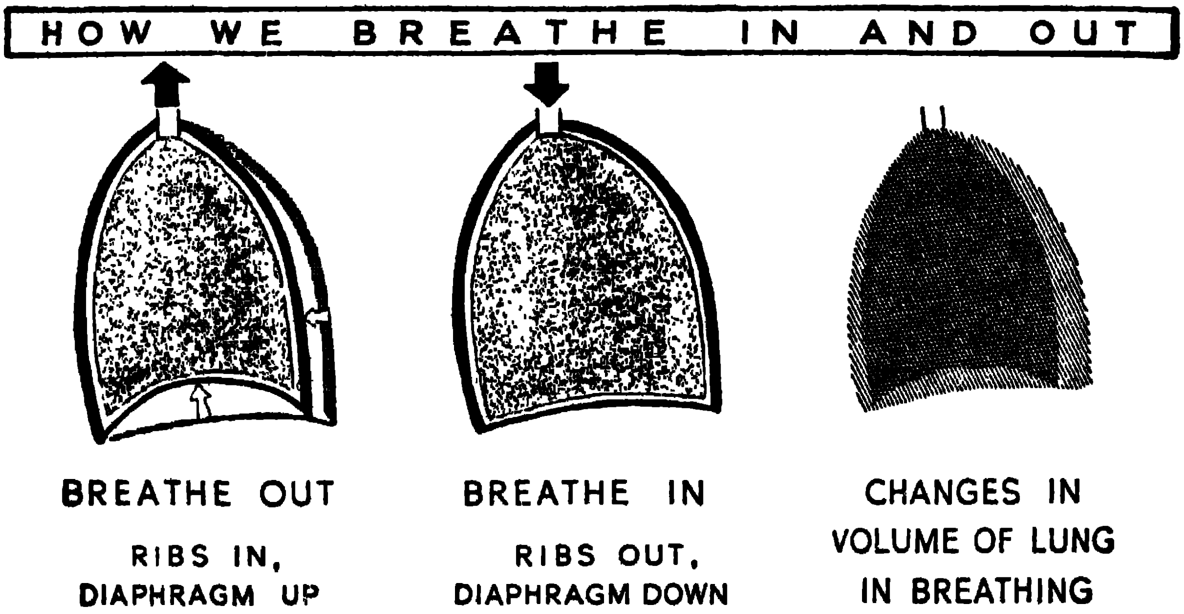


FIG. 8.—Breathing movements (diagrammatic)

Examination of lungs

Examine the lungs and wind-pipe of a large mammal and draw their external appearance from the ventral view. Identify (*a*) the *voice-box*, (*b*) the *epiglottis*, a lid-like structure which closes the opening to the wind-pipe when swallowing. Look down inside the voice-box and notice the *glottis*, a narrow slit, with the *voice-cords* on either side. Slit open the voice-box and find the voice-cords.

Examine the wind-pipe and notice how it is stiffened by 'C'-shaped rings of gristle so that it is always kept open. Slit open the wind-pipe to where it divides into two branches. Then slit open one of these branches and follow its course as it divides again and again into smaller and smaller air-tubes. At the same time, identify the arteries and veins running through the tissues of the lungs.

THE TRANSPORT OF FOOD AND OXYGEN IN THE BODY

We have now briefly described how soluble, diffusible foods are formed in the intestine during digestion, and how the air in the lungs is constantly renewed during the movements of breathing. Now the actual oxidation of food and the building-up of new materials go on in the individual *cells* of every part of the body. In mammals a most complex system exists which transports food from the intestine to these body-cells and also carries to them oxygen from the lungs. The same system removes waste products from the cells and also helps to equalize the temperature of the body. It is called the *vascular system*, and the liquid which acts as the transporting agent is the *blood*.

The vascular system

The blood is carried in a complicated network of *blood-vessels*, which together form the vascular system. This differs from the vascular system in plants (which also carries water and food materials) in that it is a 'closed' system, the tubes of which it is made being all connected into a closed network of blood-vessels. Water, gases, and other chemical substances, however, can and do pass easily into and out of this 'closed' system through the thin damp walls of the *capillary* vessels.

In all the higher animals, the vascular system consists of (*a*) a *heart*, (*b*) *arteries*, (*c*) *veins*, (*d*) *capillaries*. The heart is a muscular pump that forces the blood round the body *away* from the heart along the arteries. The veins are the blood-vessels that carry the blood *towards* the heart. The capillaries are very fine blood-vessels that join arteries to veins and bring the blood close to the living body-cells.

The heart, which in Man is about the size of a closed fist, lies inside the chest-cavity, between the lungs. It is enclosed in a delicate double-walled sac, the *pericardium* (see Fig. 3), and we may regard the heart simply as two muscular pumps lying side by side, each with two compartments. The left heart-pump (see Fig. 9) receives the 'fresh' blood (i.e. blood containing oxygen) from the lungs and pumps it to all the other parts of the body. The blood returns from these organs poor in oxygen and rich in carbon dioxide, and passes to the right heart-pump, which sends it round through the lungs to the left heart-pump again. In its passage through the lungs the blood loses carbon dioxide and takes up a fresh supply of oxygen. In its passage around the *body* the blood loses oxygen (which is used in oxidation) and takes up dissolved food and the waste product carbon dioxide. The right heart-pump is only concerned with sending blood to the lungs, while the left heart-pump is concerned with sending blood to the rest of the body.

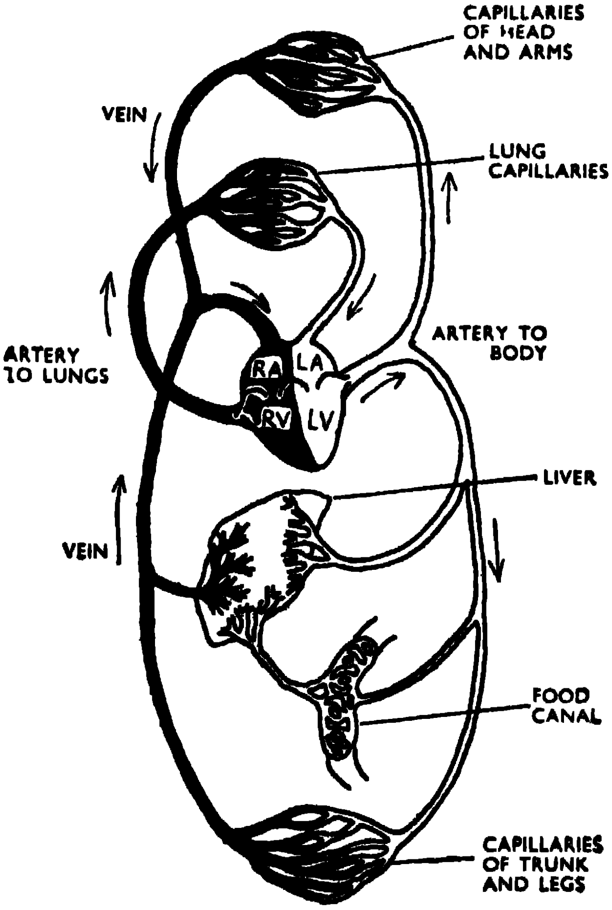


FIG. 9.—Blood system of mammal (diagrammatic)
(Oxygenated blood unshaded: de-oxygenated blood shaded)

Important Note. When describing parts of an animal as 'left' or 'right', imagine yourself to be standing behind the animal and looking towards its head (or imagine yourself in the animal's place). Since Man stands upright, on his hind limbs with his backbone vertical, while most other mammals stand on all four limbs with their backbone horizontal, the terms 'back' or 'front' may be very confusing. In describing the position of the parts of *any* animal's body, therefore, we use the terms *anterior* (= 'towards the head'), *posterior* (= 'away from the head'), *dorsal* (= 'on or near the back'), *ventral* (= 'towards the belly-surface' or 'away from the back'). In books describing the structure of Man in particular the terms 'superior' or 'inferior' are substituted for 'anterior' and 'posterior', but for the ordinary educated citizen it is simpler to use one set of terms that will apply to animals in general rather than learn a special system for one particular animal—Man. You will notice that in Figs. 1, 3, and 11 the organs are drawn as they would appear in a dissection, i.e. as seen from the ventral side. The right-hand organs therefore appear on the left of the diagram.

The heart of an adult man at rest beats about 70–80 times a minute. Each 'beat' consists of the emptying of the four chambers of the heart, followed by their filling while the heart muscles rest for a short interval. The heart-beat can be felt just below the fifth rib on the left side of the chest, because at each contraction the left heart-pump presses against the chest wall at this point. The heart-beat can also be counted by feeling the *pulse*, which is the wave of pressure that passes down the arteries following each contraction of the heart-pump. The pulse may be felt wherever an artery comes close to the surface of the body, and especially when it is backed by bone as at the wrist and temple or inside the elbow and ankle.

(1) Feel the pulse in the left wrist. Place the right hand with the palm pressing against the back of the left wrist and bend the fingers round until the pads of the middle and index fingers lie on the wrist just above the ball of the thumb. The pulse may be safely stopped (for a short time) if you get someone to press on the artery which runs along the inside of the left arm just above the elbow.

(2) After counting the pulse, do some vigorous exercise for 30 seconds, e.g. 'knees up' or skipping. Then count the pulse again and note that exercise increases the rate of the heart-beat; this is reflected in the increased rate and greater 'bounce' of the pulse.

When the left heart-pump forces blood into the main artery (or *aorta*) and thence to the arteries, these tubes are stretched, but their walls are elastic and between the heart-beats they continue to squeeze blood along the tubes in a direction *away* from the heart, because the walls tend to return to their original position and the *valves* (see Fig. 10) of the heart prevent back-flow. Thus a fairly steady blood pressure is kept up in the arteries, which is increased for a time after each fresh contraction of the heart-pump. When a man of average size is at rest, his left heart-pump delivers about 2½ pints per minute. The total amount of blood in a man's body is about 10 pints.

Most arteries run well below the surface of the body and they are only damaged by severe injury. If an artery is cut the fact may be recognized because (*a*) the blood spurts out from the wound in a series of jerks, (*b*) it is bright red, and (*c*) the flow may be stopped if pressure is applied to the artery or flesh on the side of the wound which is nearer to the heart. When a large artery is cut, an animal is in serious danger of bleeding to death unless such pressure can be quickly applied. The blood in the large arteries is pushed along them at speeds as great as 50 cm. per second. The loss of blood, therefore, is rapid and the size of the leak is so great that enough pressure to supply the brain cannot be maintained in the rest of the circulation, and the victim becomes unconscious.

By the time the blood has reached the capillaries into which the arteries branch, it is travelling much more slowly, at a rate nearer 0·5 mm. per second. These capillaries are too small to be seen with the naked eye and in them the pulse is lost. They run through all parts of the body and are numerous in the surface skin. If they are cut (as when we prick a finger or graze the skin), the blood oozes from them very slowly, and it very quickly *clots* (see p. 156).

From the capillaries the blood passes slowly into the veins, which often run near the surface (they can most easily be seen under the skin on the back of the hand). A cut vein bleeds without spurting (there is no pulse in veins); the de-oxygenated venous blood is at first dark red, and the bleeding may be stopped by pressure on the side of the wound *away* from the heart. Veins differ from arteries in that most of them contain valves which prevent the backward flow of blood, while the pressure in them is never high. The movement of the blood towards the heart is helped by the body-muscles near the veins, when these muscles contract during the normal movement of an animal. If we stand still for a long time the blood is not in this way squeezed back to the heart quickly enough; it then tends to collect in the veins of the legs and the shortage of blood in the head may cause us to faint.

The lung circulation

A simplified diagram of the circulation of the blood is shown in Fig. 9. The two upper (anterior) chambers of the heart are known as the *auricles*; the lower (posterior) pair are the *ventricles*, and these, especially the left ventricle, are very thick-walled. The de-oxygenated dark red venous blood, rich in carbon dioxide and coming from all parts of the body (except the lungs), flows into the right auricle, which contracts regularly and pumps it into the right ventricle (see Fig. 10). When turn and forces the blood through a large artery towards the lungs. Valves between the auricle and ventricle and at the entrance to the artery ensure that the blood does not pass back from ventricle to auricle, nor from the artery to the heart, during the relaxation of the ventricle at the end of its 'stroke'. In the lungs the arteries divide into smaller branches, and these divide again and again to form very narrow or *capillary* blood vessels, which run through the thin walls surrounding the air-sacs in the lungs (see Fig. 5). As the blood passes into these tiny capillaries, it not only exposes a larger surface, but its rate of movement is very greatly slowed down (as when a river flows into a swamp). Thus in the lungs the blood travels along very slowly and there is time for gaseous exchange to take place. The blood, of course, never comes into actual contact with the air in the lungs, but is separated from it only by the thin walls of the capillaries and of the air-sacs; these walls are always wet, so that carbon dioxide and oxygen dissolve in the water in the thin walls and pass through them. There is always a considerable loss of water from the lungs, removed in the expired air, for the thin wet walls lose water by evaporation into the spaces of the

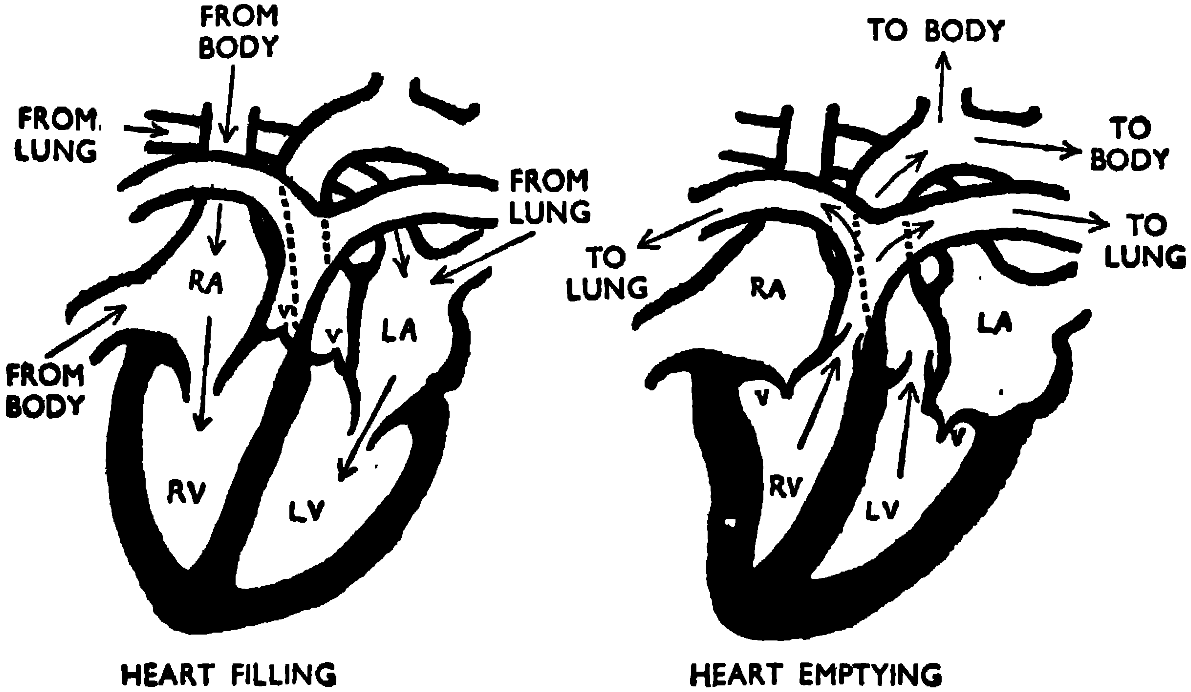


FIG. 10.—Action of heart (diagrammatic)

RA: right auricle
RV: right ventricle
LA: left auricle
LV: left ventricle
V: valve

lungs. This evaporation is, however, diminished if breathing has taken place through the nose (see p. 13).

The exchange of gases between blood and air in the lungs takes place by *diffusion* (see also p. 84). The gases, carbon dioxide and oxygen, pass from places where they are in high concentration to places where they are in lower concentration. Hence in the capillaries of the lungs, oxygen passes from the air-sacs into the blood and carbon dioxide from the blood into the air-sacs. The capillary blood-vessels, which form a fine network in the lungs, all join together again to form large veins which carry the *oxygenated* and 'carbon-dioxide-poor' blood (which is now a bright red) to the left side of the heart.

Blood consists of a watery 'plasma' containing dissolved food substances and numerous small suspended red blood-cells containing the colouring matter *haemoglobin*. This substance plays a most important part in the transport of oxygen. It is normally dark red, as we see it in the veins. When combined with oxygen (as in the arteries, or when the blood is exposed to air) it becomes bright red. Owing to the presence of haemoglobin, the blood can take up, in the form of a loose chemical compound, about forty times as much oxygen as it does by the simple solution of oxygen in the watery plasma, i.e. without haemoglobin the heart would have to pump blood at about forty times the normal rate to keep the body-cells supplied with oxygen. The loose compound *oxy-haemoglobin* is formed in the capillaries of the lungs and easily breaks down again in the capillaries of the rest of the body, the oxygen being taken from it and used in respiration. The carbon dioxide given out by the body-cells is also taken up by the blood, partly in combination with the haemoglobin, but mostly by other complex chemical reactions, and it is readily released again from the blood in the capillaries of the lungs.

The body circulation

Bright-red oxygenated blood from the lungs enters the left auricle (see Fig. 10), whence it is pumped into the left ventricle through another non-return valve. This ventricle in turn contracts and the blood is forced through yet another valve into the largest artery, the *aorta*. This branches and distributes the blood to smaller and smaller arteries, which carry the blood to capillary blood-vessels, thus supplying food and oxygen to all parts of the body (except the lungs which have their own separate circulation). From the capillary blood-vessels of the body-circulation, the blood is collected by veins that join together and finally bring this de-oxygenated blood, which has given up part of its oxygen and has taken up carbon dioxide and dissolved food, to the right side of the heart. This completes the body-circulation, and the right heart-pump sends this de-oxygenated blood to the lungs once more. The veins leading from the capillaries of the *gut* do not pass the blood directly back to the heart; they join together into a large *portal* vein, which passes to the liver and there branches again into capillaries. The liver is a sort of chemical laboratory for the body; sugary food brought to it in the blood along the portal vein is dealt with here, some of it is stored as a starch-like substance, *glycogen*, while the rest passes on, by way of the heart, to the other parts of the body. The liver also deals with any proteins not required for body-building, breaking them down and liberating sugars (which are used in respiration), together with

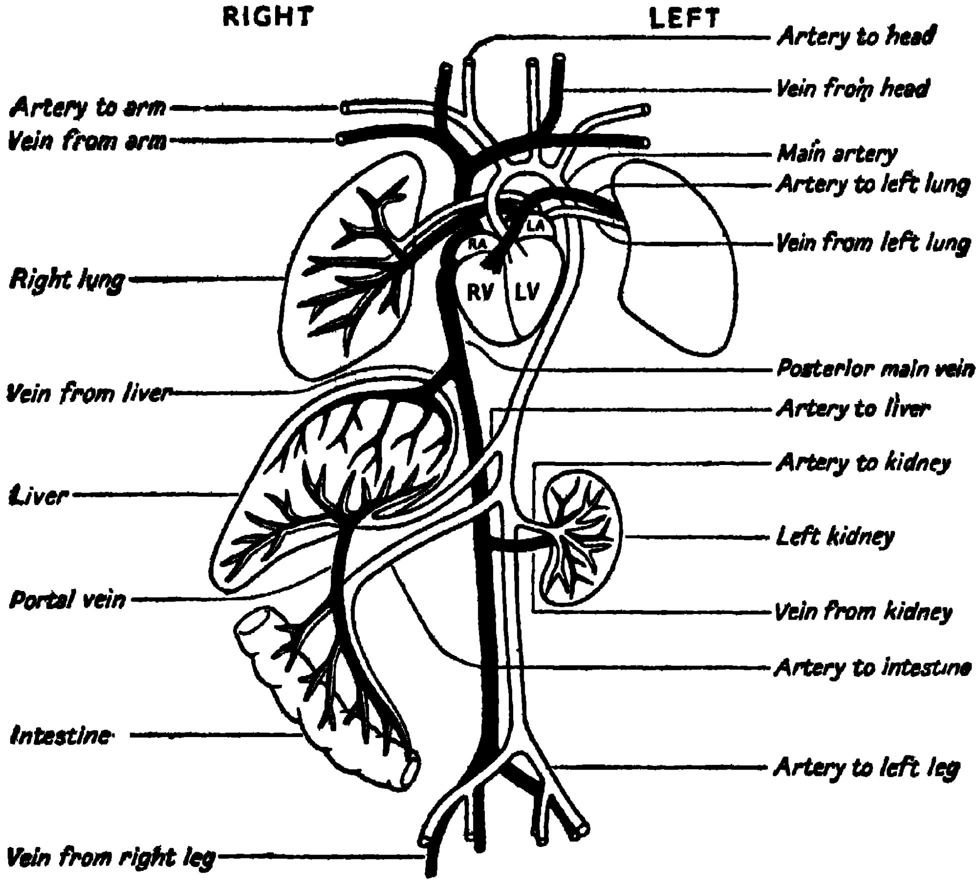


FIG. 11.—Diagram showing principal blood-vessels

Vessels containing de-oxygenated blood are shaded black. The right kidney is omitted. RV—Right ventricle. LV—Left ventricle. RA—Right auricle. LA—Left auricle.

the waste product *urea*, a substance which is later removed from the body by the *kidneys*. The living cells of the liver obtain their oxygen from blood brought directly to them in the *hepatic artery* (see Fig. 11).

Scientific men have known something of the construction of the vascular system in animals for nearly two thousand years, but it was not until the seventeenth century that a clear account of the circulation of the blood was given by Harvey. When you have seen an animal dissected and have noted the great complexity of the vascular system, you will understand the difficulties which stood in the way of the work. The early scientists believed, for example, that the right and left sides of the heart communicated directly with each other, and they were very confused by the fact that the artery to the lungs carried dark red venous blood, while the aorta and other arteries to the body carried bright red blood. A combination of careful and accurate *observation and experiment*, coupled with a better understanding of the chemistry of respiration, opened the way to our modern knowledge which we can now summarize in diagrams like Figs. 9, 10 and 11.

THE BLOOD

We have seen that the blood is concerned with *transport* in the animal body. *It carries* (*a*) *food from the intestines to the body-cells*, (*b*) *oxygen from the lungs to the body-cells*, (*c*) *waste products from all parts of the body to the lungs and kidneys*, (*d*) *heat produced by working muscles, and* (*e*) *hormones* (see p. 114).

The average man has about 10 pints of blood in his body. Under resting conditions only part of this blood is actually circulating, the rest being held in reserve, mainly in the *liver* and *spleen* (see p. 158). The blood makes up about 1/11th of a man's body-weight.

When a drop of blood is spread out into a thin film and examined under the microscope, it is seen to consist of a clear, colourless liquid, *plasma*, in which float *blood-cells*. These blood-cells are of two distinct kinds—*red blood-cells* and *white blood-cells* (see Fig. 12).

Red blood-cells

The red blood-cells (or *red corpuscles*), which are from 500 to 1,000 times more numerous than the white cells, are shaped something like a concave lens, i.e. they are circular in outline and thicker round the edge than in the middle. Under the microscope they appear yellow, but when seen massed together in large numbers, e.g. in a drop of blood, they appear red. This red colour is due to the presence of *haemoglobin*, a protein substance containing iron, which readily combines with oxygen.

These red blood-cells are formed in the red *marrow* of bones, and then they enter the blood-stream, where their active life lasts for a few weeks only. After this they are broken down in the *liver* and in the *spleen*, some of the waste products being excreted in the *bile*. In this way millions of red blood-cells are destroyed and replaced every second.

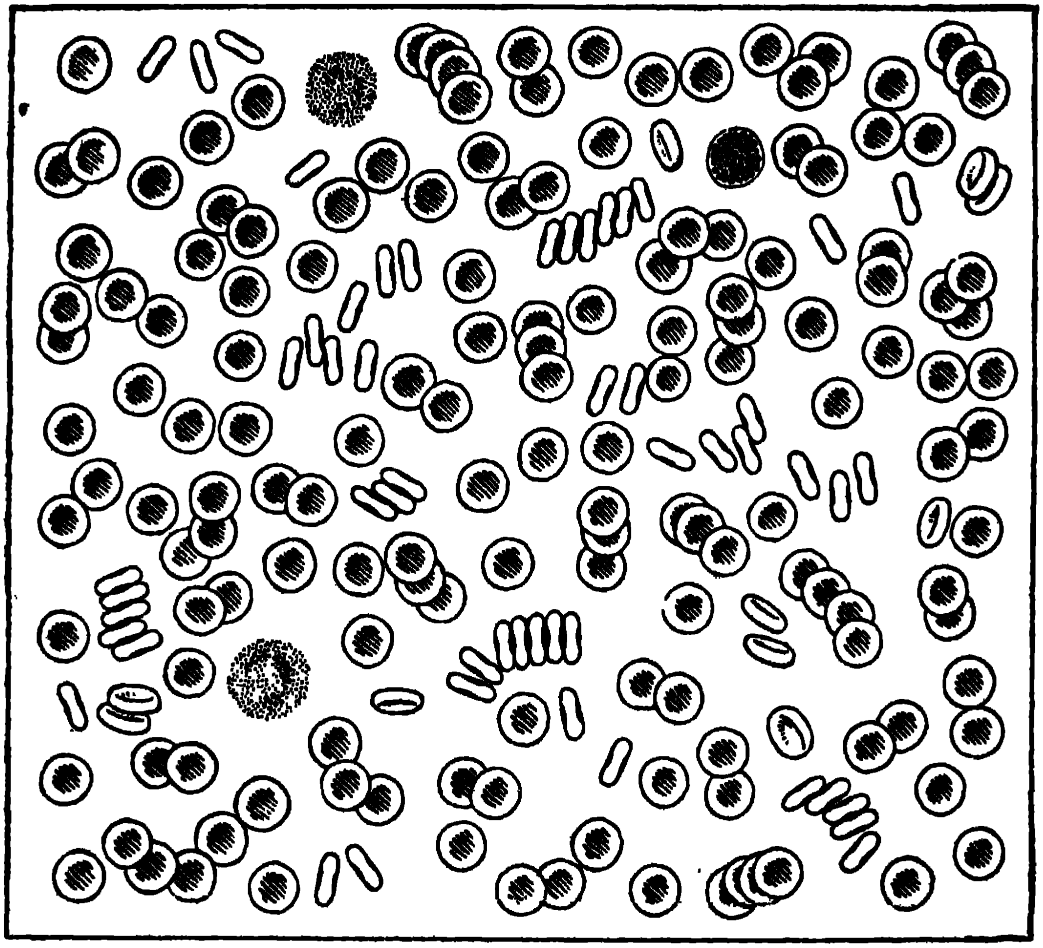


FIG. 12.—A drop of human blood seen under the microscope, showing many red blood-cells and three white blood-cells (highly magnified)

White blood-cells

The white blood-cells (or *white corpuscles*) are much fewer in number than the red cells. There are usually between 500 and 1,000 red cells to every white cell. Some of the white blood-cells are formed in the red bone marrow, others in the *lymph glands*, and their active life lasts for a few days only. Unlike red blood-cells, the white corpuscles have no definite shape and can thus squeeze through the thin walls of the capillary blood-vessels and reach almost any cell in the body.

There are several kinds of these white blood-cells. One kind of white cell surrounds and digests bacteria which may enter the body, thus defending the body against bacterial infection. One of these white cells may surround and digest as many as twenty invading bacteria (see Fig. 13). Some white blood-cells also set free substances which are poisonous to bacteria. In the normal healthy body, these white blood-cells are victorious over the bacteria that enter the body. If the skin is cut or broken, white blood-cells collect in large numbers to remove bacteria and damaged body-cells. The *pus* which collects round some wounds consists mainly of dead white blood-cells, dead bacteria, and decomposed body-cells.

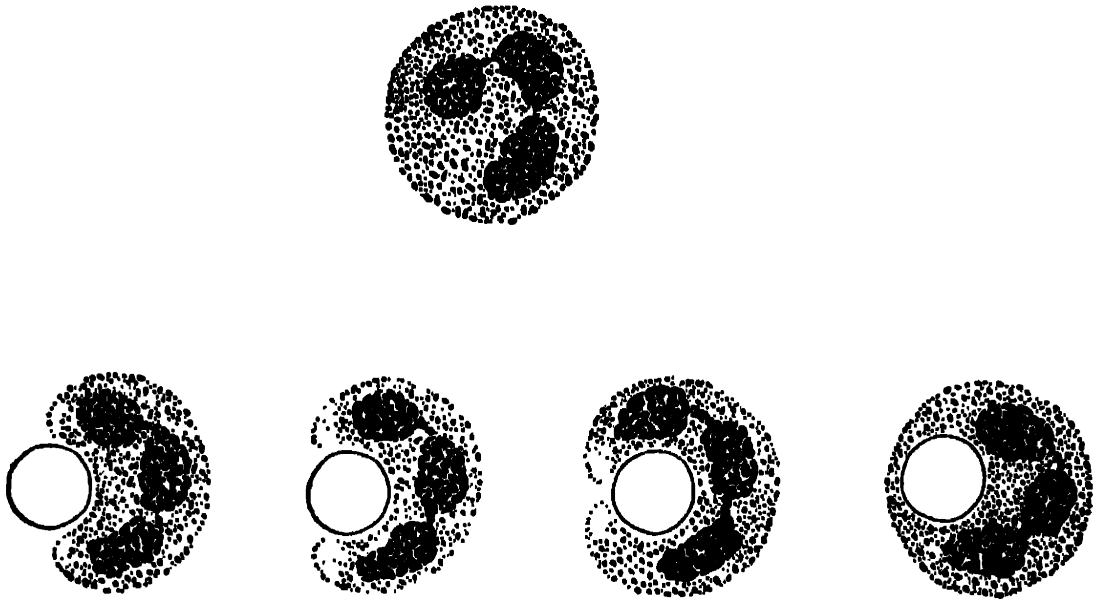


FIG. 13.—A white blood-cell surrounding a micro-organism (highly magnified)

Tissue-fluid and lymph

As the blood flows slowly through the capillaries, some of the watery blood-plasma (and some of the white blood-cells) escapes through their extremely thin walls and surrounds the neighbouring body-cells. This *tissue-fluid*, which you may regard as blood without its red cells, surrounds all the body-cells and fills the tiny spaces between the body-cells and the capillary blood-vessels, acting as a 'go-between' or 'middle-man' between the blood on the one hand and the body-cells on the other. The tissue-fluid takes oxygen and food materials from the blood and hands them on to the body-cells. At the same time, it takes up carbon dioxide and other waste products from the body-cells. This 'used' tissue-fluid is known as *lymph*.

Since tissue-fluid is always escaping from capillaries all over the body, the lymph it forms will have to be collected up again and returned to the blood-stream once more. Some of it re-enters the capillaries and is carried on to the veins, but the remainder enters small *lymph-vessels* that later unite to form larger vessels which finally open into large veins near the heart, thus returning the lymph once more to the blood-stream. The amount of lymph passing through the lymph-vessels is only about 10 pints (4–5 litres) per *day*. The lymph-vessels have even thinner walls than veins and since the lymph they contain is almost colourless, the *lymphatic system* is very hard to make out in an ordinary dissection. In Chapter 2 you will learn that digested *fats* are absorbed from the intestine through the lymph-vessels.

EXCRETION

In its widest meaning, the term *excretion* means the removal of all waste matter from living things. In green plants, the waste matter consists of (*a*) carbon dioxide, produced during respiration, and (*b*) excess oxygen, produced during photo-synthesis. These are easily lost to the surrounding air, no part of the living plant being far from the surface or from an internal air space. With plants a great deal of water is lost (transpired), but as we do not usually regard this water as waste matter, transpiration is not regarded as a form of excretion. Moreover, the water is not actually pushed out of the plant, but simply evaporates from exposed wet surfaces within the leaves.

Animals, with their more compact bodies, cannot get rid of the waste product, carbon dioxide, so easily as plants; moreover, they usually produce an excess of nitrogen-containing waste substances. There are, in all higher animals, special *excretory organs*, which remove these waste materials from the body.

Of the food taken into the food-canal of a mammal, a certain proportion is indigestible and is never absorbed into the blood-stream. This unabsorbed, more or less solid, waste passes through the food-canal and is finally excreted at the *anus* as *faeces*. Strictly speaking, this undigested matter has never been inside the living cells of the animal's body. The food-canal is open to the outside world at both ends—mouth and anus—and it is only after the digested part of the food has passed through the walls of the food-canal that it is considered to have entered the true interior of the body.

The digested food is absorbed into the blood-stream and passes to the living cells. As a result of the complicated chemical processes which go on in these cells waste products are formed. The most important of these are (i) *carbon dioxide* (formed during oxidation of food-material), (ii) *nitrogen-containing compounds*, such as *urea* (formed when proteins are broken down) and (iii) *water*.

Most of the carbon dioxide and some of the water are given up by the blood as it passes through the lungs, and thus escape into the atmosphere each time the animal breathes out. The experiment in Fig. 14 (see also pp. 261–2) shows that the air we breathe out contains much more carbon dioxide than the air we breathe in (actually about a hundred times as much). The large amount of water-vapour in the air we breathe out can be shown by breathing on to a sheet of polished glass: it becomes covered with drops of condensed water.

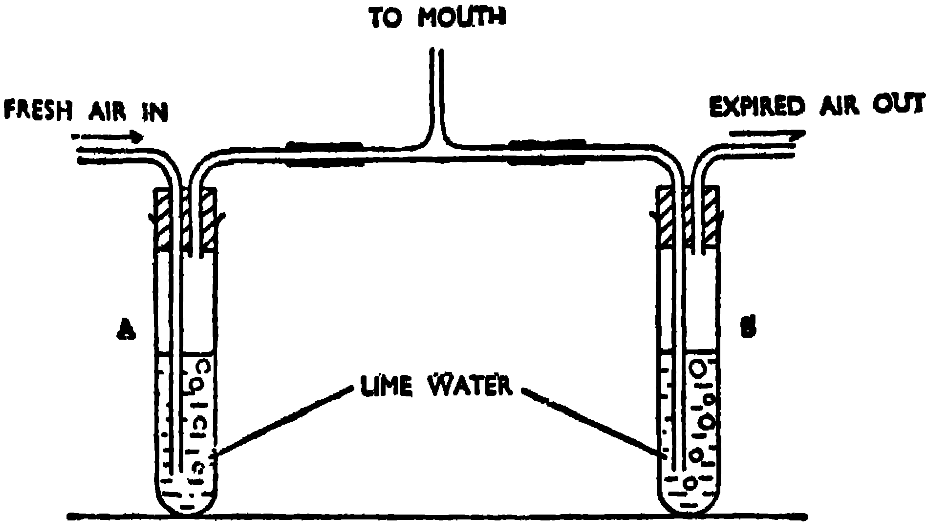


FIG. 14.—Changes produced in air by breathing

Animals contain a much larger proportion of protein than plants, and they produce larger quantities of nitrogenous waste products, which are excreted by special organs. In mammals, the *kidneys* remove *urea*, dissolved in water, from the blood. The kidneys consist of numerous microscopic tubules in close contact with capillaries carrying blood. Water, urea and some salts pass from the blood into these tubes, which join together into *kidney-ducts*, or *ureters*, that lead into the *bladder*. The solution—*urine*—drains through the ureters into the *bladder*, where it is stored up and passed out at intervals (see Fig. 15).

The greater part of the waste products, therefore, are got rid of through the *lungs* and through the *kidneys*. In some mammals, however, large quantities of water are lost by the *skin* as *sweat* if the outside temperature is high, but this loss of water which takes place during sweating is *not* to be regarded as the *excretion* of waste products; like transpiration in plants, sometimes it may actually be harmful. However, apart from any question of excretion, the evaporation of sweat from the skin is accompanied by cooling of the body, hence sweating is a process which is more important in connexion with the regulation of body temperature than as a method of excretion.

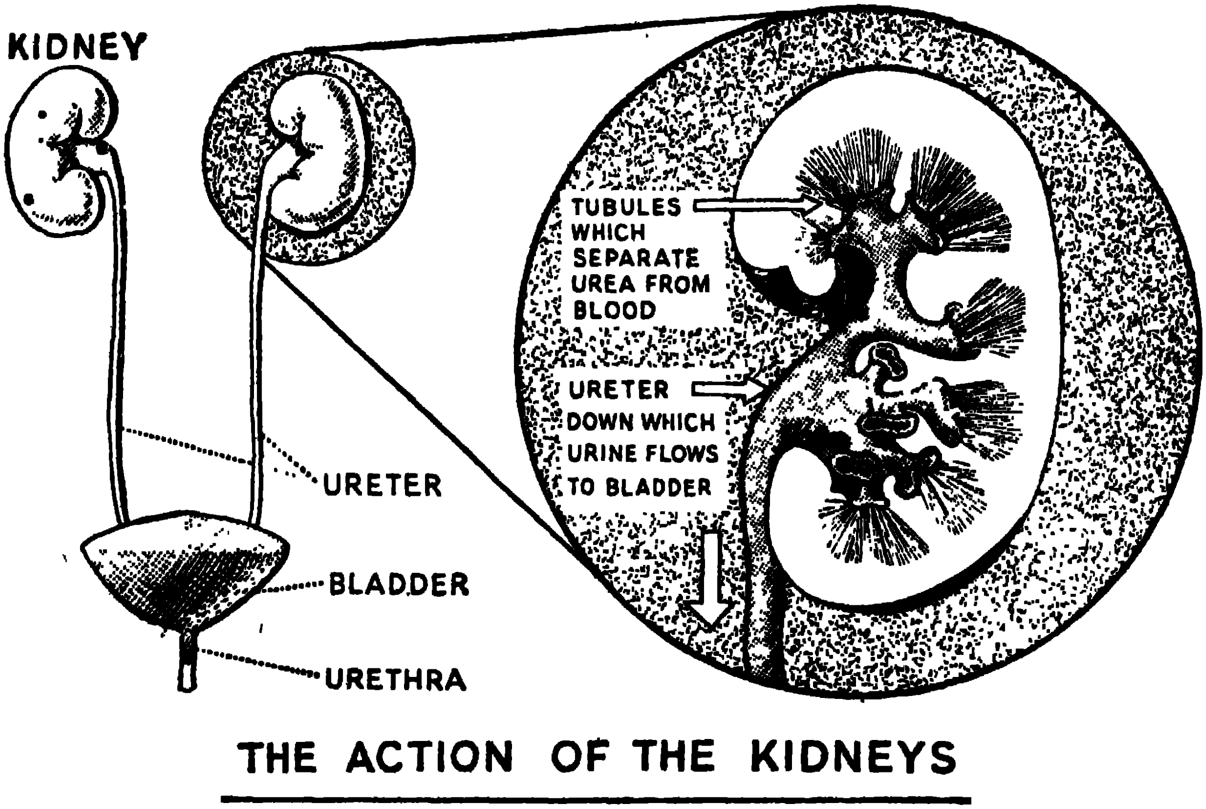

KIDNEY
TUBULES WHICH SEPARATE UREA FROM BLOOD
URETER DOWN WHICH URINE FLOWS TO BLADDER
URETER
BLADDER
URETHRA
THE ACTION OF THE KIDNEYS

FIG. 15.—Kidney structure

CELLS AND TISSUES

Every living thing is built up of very small units called cells. Cells were first described by Robert Hooke in the seventeenth century, when he noticed the 'honeycomb' appearance of a thin slice of cork when viewed through the microscope. He gave the name 'cell' to each tiny box in the 'honeycomb' (see Fig. 16). This name was rather unfortunate, for it suggests a hollow, empty box; yet *living* cells are neither empty nor hollow. The cork which Hooke examined was dead, and the living contents of the cells had disappeared. What Hooke saw was merely the dead *cell-walls.* Nearly 200 years later, it was found that the living parts of plants and animals are made up of cells containing a semi-liquid living jelly, which is called *protoplasm*, and nowadays the term 'cell' is applied to the living contents (the protoplasm) rather than to the dead case (the cell-wall).

Plant-cells (see Fig. 16) are surrounded by a dead cell-wall composed of *cellulose* (a carbohydrate). Animal-cells have no such cell-wall, hence it is more difficult to distinguish the outline of individual animal-cells under the microscope. The easiest way of seeing some animal-cells for yourself is to scrape the inside of your cheek with your clean finger-nail and put the scraping in a drop of water on a microscope slide. Under the microscope can be seen the thin, flat, overlapping cells which cover the inside of the mouth. The greater part of each cell consists of colourless, jelly-like *protoplasm*, the outer layer of which is a little more solid than the remainder, thus forming an elastic, living membrane. In the middle of each cell is the rounded *nucleus* which controls all the activities of the cell. Such cells, of different patterns, shapes, and sizes, are the units from which an animal's body is built up.

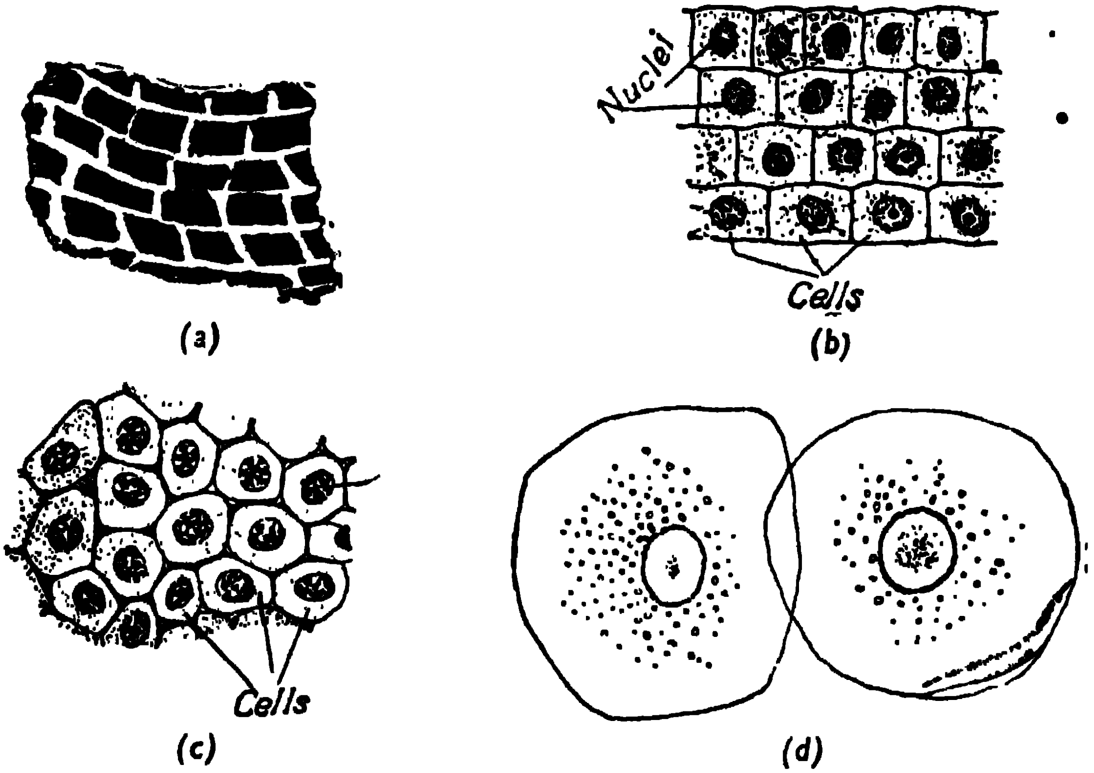


FIG. 16 (highly magnified)

(*a*) Hooke's drawing of cork cells
(*b*) Plant-cells from young root
(*c*) Frog skin-cells
(*d*) Cells from inside of cheek

Each individual living cell, however, is a living thing in itself and, under suitable conditions, it can be separated from the rest of the body and kept alive (by the method of 'tissue-culture'). *Each single cell carries out all the living processes*, e.g. it feeds, respires, and grows. Besides this, when a cell reaches a certain size, it may divide into two parts, each containing half the original nucleus, i.e. *each living cell can reproduce itself*. We see, therefore, that a single cell—a particle of protoplasm controlled by a nucleus—is the simplest living thing,[1] containing in its tiny body everything necessary for life. The simplest animals and plants are microscopic in size and consist of only one single cell. In these, as well as in much more complex organisms, all the essential functions of life take place *in the individual cells*.

Tissues

The body of a higher animal or plant is built up of many different kinds of cells, each cell being adapted to carry out some particular function; in other words, the higher animals show *division of labour*. For example, some cells are nerve-cells, some are muscle-cells, some are reproductive cells, and so on.

Each of these special kinds of cells performs one special function better than any other, and masses of such specialized cells are grouped together to form *tissues*. For example, masses of nerve-cells are known as *nerve-tissue*; large numbers of muscle-cells form *muscle-tissue*. Other kinds of specialized cells form *covering-tissue*, *binding-tissue*, and *strengthening-tissue*.

Organs

Complicated body-structures like the heart, stomach, liver, brain, eye, and ear are called *organs*, and every organ is formed of a number of different *tissues*. The eye, for example, contains covering-tissue, binding-tissue, muscle-tissue, nerve-tissue, and blood-tissue, each tissue carrying out its own special work, but all of them working together as parts of a single organ carrying out a *minor* function of the body.

Systems of Organs

In the body of a higher animal, the various organs are grouped together into *systems*, each system having its own special work in carrying out a major function of the body. For example, all the digestive organs—mouth, tongue, throat, gullet, stomach, intestine, salivary glands, liver, gall-bladder, and pancreas—together form the *digestive system*. In studying the higher animal we have to consider the *skeletal system*, the *muscular*

---

[1] Apart from a *virus* (see p. 203), which is non-cellular.

system, the *respiratory system*, the *digestive system*, the *blood system*, the *excretory system*, the *nervous system*, and the *reproductive system. The animal body, or the complete ORGANISM, therefore, is built up of SYSTEMS; these systems are built up of a number of ORGANS; the organs are made of several different TISSUES, which are collections of similar CELLS, the cell being the smallest living unit.*

THE SKELETON

Mammals are built around a framework of *bones*, called the *skeleton*. These bones not only stiffen the body and give the animal its definite and characteristic shape, but they also help in *movement*, for most of the *muscles* are attached to them. Parts of the skeleton, the *skull* and the *backbone*, also protect the delicate *brain* and *spinal cord*.

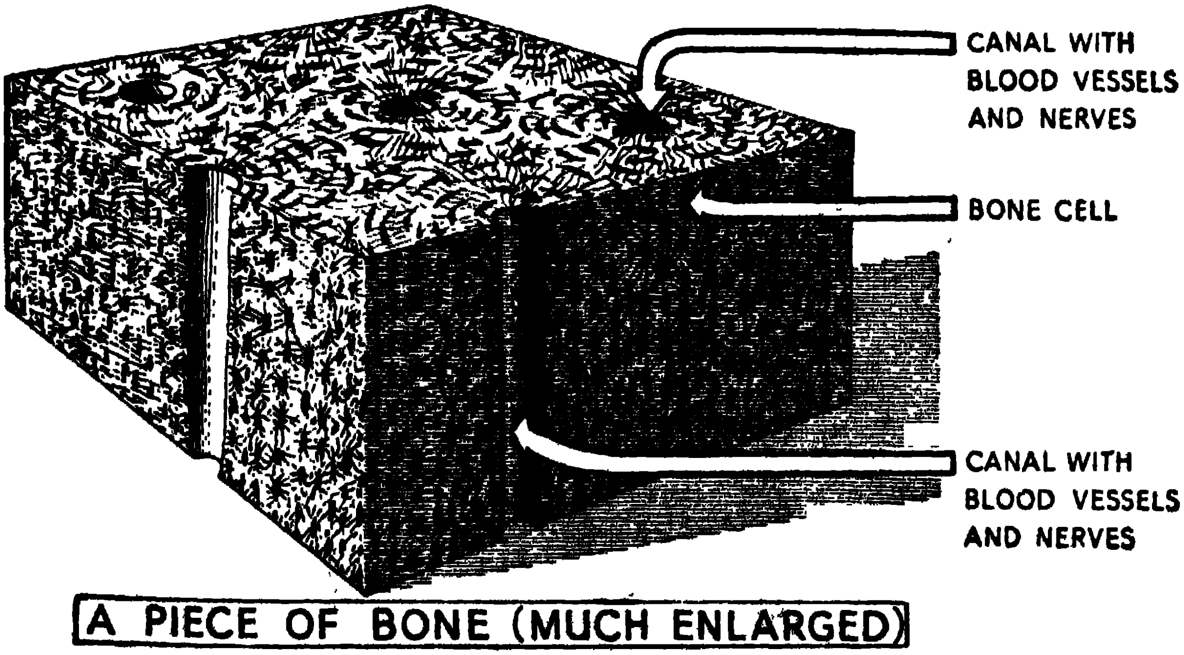

CANAL WITH BLOOD VESSELS AND NERVES
BONE CELL
CANAL WITH BLOOD VESSELS AND NERVES
A PIECE OF BONE (MUCH ENLARGED)

FIG. 17.—Bone structure

The bones of a living animal are themselves alive, being supplied with blood vessels and nerves (see Fig. 17). They grow, like the other softer parts of the body; in a very young animal they are soft and flexible, but later they become brittle and hard. If a bone is broken the two parts are capable of 'growing together again', i.e. new bone is formed across the breakage.

Bones are very rich in calcium and phosphorus compounds, but, being alive, they also contain *organic* matter. If a bone is heated red-hot, all

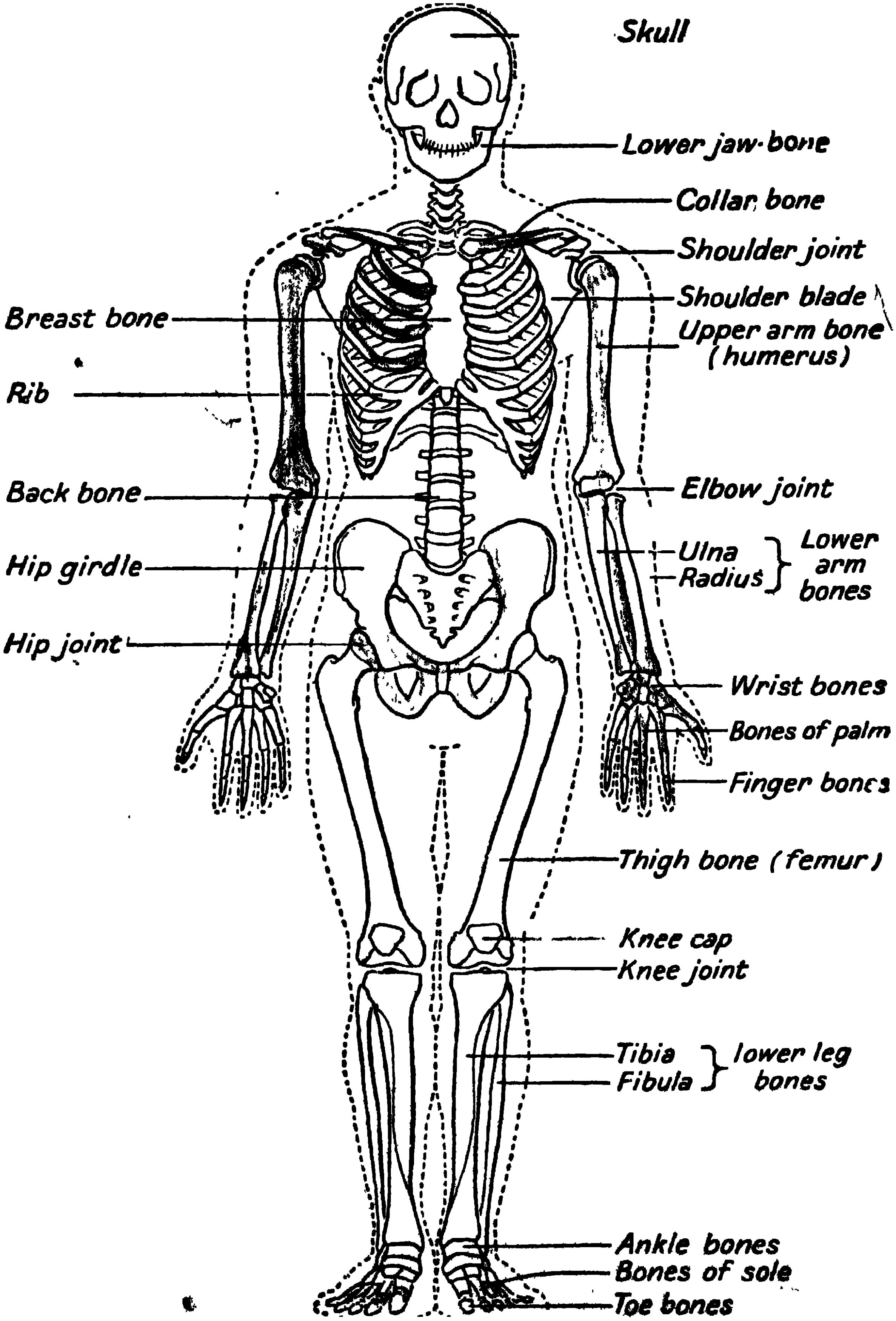


FIG. 18.—The human skeleton

the organic matter burns away and only the hard *inorganic* (or mineral) matter is left. If a bone is treated with dilute hydrochloric acid, the mineral matter (calcium carbonate and calcium phosphate) dissolves and only the soft organic matter is left. The inorganic matter makes bone very dense, and most of the larger bones are hollow, giving equal strength with less weight.

This bony framework is built on the same essential ground-plan in all the *vertebrates* (the animals with *backbones*), e.g. fish, frog, bird, and mammal, consisting of a *main axis* (*skull*, *backbone*, *ribs*, *breastbone*) and two pairs of attachments (limbs), which may be either legs or arms or fins or wings. These are attached to the two *limb girdles* which form part of the skeleton (see Fig. 18). An internal skeleton does not give such complete protection to the soft parts of the body as does the external skeleton of an insect, but it offers no hindrance to growth and is better adapted to free body-movements.

The skull

The skull, or head-skeleton, is built up of a number of plate-like curved bones joined together at their edges (see Fig. 18). It gives protection to the soft, delicate brain and to the sense-organs—eyes, ears, and nose. It also carries the *jaws*. The upper jaw is firmly attached to the skull, while the lower jaw is attached by tendons and muscles, being freely hinged to move up and down. The lower jaw can also move slightly from side to side, and (in gnawing mammals) from back to front.

The backbone or spinal column

The skull is hinged to the backbone, which is built up of a large number of separate bones (*vertebrae*) joined together, end to end, by ligaments, so as to form a strong column which can twist and bend slightly (see Fig. 18). The separate bones are prevented from rubbing or striking against each other by disc-shaped cushions of *gristle*, or *cartilage*, a stiff, but elastic, substance. The cushions of gristle act as 'shock-absorbers', protecting the spinal cord from shock at every step.

This backbone forms the main axis of the skeleton. Each separate bone has a hole through it, so that when all the bones are joined, end to end, these holes form a continuous tube running from the skull down through the length of the backbone. The *spinal cord*, which arises from the hinder end of the brain, runs through this tube inside the backbone and is thus protected from harm (see Fig. 23).

The ribs

In mammals the ribs form part of a bony cage enclosing the thorax, or chest-cavity. In Man, there are twelve pairs of ribs and they are all attached to the backbone by tough, fibrous ligaments (see Fig. 18). The first seven pairs of ribs (counting from the anterior end) are also attached to the breastbone in front. The front ends of the next three pairs of ribs are not attached directly to the breastbone but to a piece of gristle that joins them to the breastbone, while the last two pairs are attached to the backbone only.

The limbs

The *fore-limbs* are connected to the trunk through the *shoulder-girdle*, which consists of a pair of *shoulder-blades* and a pair of *collar-bones*. The shoulder-blades are large, triangular bones and they are attached to the backbone and ribs by strong muscles and tendons (but there is no *bony* connexion). The collar-bones are small, curved bones connecting the outer end of the shoulder-blade with the breastbone, thus supporting the fore-limbs.

The upper part of the fore-limb (the upper arm in Man) consists of a single long bone (*humerus*), jointed to the shoulder-blade on the 'ball-and-socket' principle. The lower part (the lower arm or fore-arm in Man) consists of two bones (*radius* and *ulna*), jointed to the upper-arm bone at the elbow. Then there are several wrist-bones, and beyond these the bones of the hand and fingers.

The bones of the *hind-limbs* are connected to the *hip-girdle*, and this, in turn, is firmly attached to the backbone. Hence the hip-girdle is much more rigid than the shoulder-girdle, which has no direct bony connexion with the backbone. This results in much greater freedom of movement in the fore-limbs than in the hind-limbs. In Man, the whole weight of the trunk is carried by the very strong hip-girdle, to which very powerful muscles are attached.

The hind-limb is built on the same general plan as the fore-limb. The strong *thigh-bone* (or *femur*, the largest bone in the body) has a rounded head, which fits into a deep socket in the hip-girdle (see Fig. 50). The lower part of the hind-limb consists of two leg-bones (*tibia* and *fibula*) joined together and hinged to the thigh-bone at the knee-joint. Beyond the leg-bones are the ankle-bones, corresponding to those of the wrist in the fore-limb and joining the leg-bones to the foot-bones. In Man, the arch of the foot gives springiness to the whole skeleton and helps to protect the brain from shock.

Every muscle of movement is attached to at least two jointed bones, and nearly all these muscles are arranged in pairs—one muscle bringing the jointed bones closer together when it contracts and the other muscle pulling the bones back to their original position once more. Feel the biceps muscle tendon in the hollow of your elbow, also the prominent tendon which joins your calf-muscle to your heel-bone. (*N.B. Tendons* join bone to muscle; *ligaments* join bone to bone.)

MUSCLES AND THEIR ACTION

Muscle plays a very important part in an animal, for all animal movements are brought about by the shortening and thickening of muscle fibres. Muscle is a form of living substance which has the power of contraction; under certain conditions it can alter its shape, increasing in thickness while decreasing in length. It is both *extensible* and *elastic.* In a mammal the muscles occupy a big proportion of the whole body, e.g. the 'fleshy' parts of the arms, legs, back, and body walls are all muscle; in fact, muscle is the most abundant tissue in the body. The red flesh of higher animals ('lean meat') is largely muscle.

When muscles shorten and thicken, they *do work*, and they obtain the energy for this from respiration, which goes on in the living muscle cells. These are well supplied with blood-vessels, bringing food and oxygen and taking away the waste products formed when the food is oxidized. Only a part of the energy set free by muscle-respiration is used in *work*; much of it appears as *heat.* In fact the chemical changes taking place in muscle-contraction supply the greater part of the heat that, in mammals and birds, keeps the animal warm.

We distinguish two chief kinds of muscles. The *voluntary muscles* are those whose movements are short and rapid and under the *conscious control* of the animal. They cover the skeleton and are connected by tough, cord-like *tendons* to bones. Most voluntary muscles are arranged in pairs, each pulling in opposite directions (though not at the same time). Fig. 19 shows how the muscles are attached to the bones of the arm and shoulder in Man. The arm is caused to bend at the elbow by the shortening and thickening of the *biceps muscle*, accompanied by a relaxation and lengthening of the *triceps muscle.*

Involuntary muscles undergo slow, sustained movements which in the main are not under conscious control. These are the muscles which alter the 'bore' or *calibre* of the digestive, excretory, and circulatory tubes, and hence serve what may be called the 'domestic arrangements' of the body—e.g. digestion, circulation, and excretion.

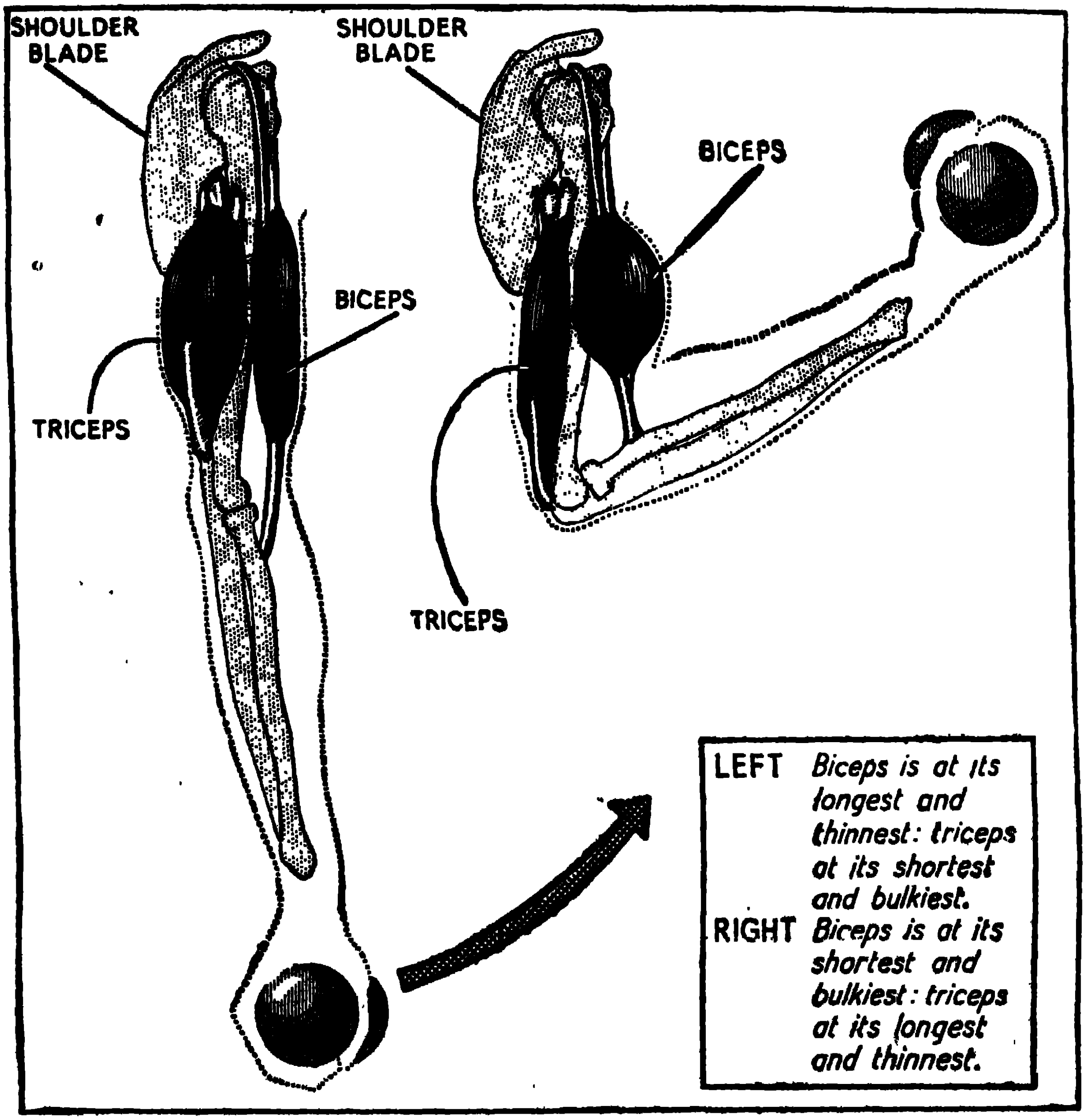

SHOULDER BLADE
SHOULDER BLADE
BICEPS
BICEPS
TRICEPS
TRICEPS
LEFT *Biceps is at its longest and thinnest: triceps at its shortest and bulkiest.*
RIGHT *Biceps is at its shortest and bulkiest: triceps at its longest and thinnest.*

FIG. 19.—Arm movements

The part played by the two kinds of muscle may be illustrated as follows: *Voluntary muscles* move the limbs which guide the food to the mouth (e.g. in Man), and move the lower jaw up and down during eating. Once the food has been swallowed, movements of the *involuntary muscles* force it along the food-canal. It is possible to spit out food that is still in the mouth, but once the food has passed into the gullet it is practically impossible to return it to the mouth.

THE SKIN

The skin, with its underlying layer of fat, separates the body from the outside world, protecting it from cold, wet, hurt, and bacterial infection. Man, especially in cold climates, assists this natural body-covering with artificial clothing. The skin also plays an important part in regulating body-temperature.

The *outer layer* of the *epidermis* (see Fig. 20) consists of *dead cells* which have become horny plates. These dead cells are usually rubbed off from time to time, but in some parts of the body, where there is pressure or friction, they accumulate and form a thick, horny layer, e.g. in Man, on the underside of the foot, the palm of the hand, and the front of the fingers and thumbs. There are few nerves or blood-vessels in this dead outer layer, hence there is little pain or bleeding when the *outer* layer is cut. As the outer layer of dead cells wears away, the cells are replaced from the layer of living cells which forms the *inner layer* of the *epidermis.*

Each *hair* arises from a narrow tube or *pit* in the skin. *Oil-glands,* opening near the root of each hair, produce an oil which makes the hair waterproof and also softens the skin. Brushing spreads this oil all along the length of the hair. Small muscles are attached to the pit enclosing the root of the hair, and when these muscles contract, the hair 'stands on end'.

In the deeper layers of the skin (the *dermis*) are *sweat-glands,* each consisting of a spiral tube, coiled into a knot at its inner end and opening at the surface of the skin through a *sweat-pore* (see Fig. 20). The sweat-pores are not evenly distributed over the surface of the body, e.g. there are about 3,000 per square inch in the palm of the hand, but only about 500 per square inch on the back. The sweat-glands are surrounded by a network of capillary blood-vessels from which they absorb water containing very small quantities of dissolved salts and urea. It is chiefly by evaporation of sweat that the body-temperature is regulated. The *dermis* contains a network of blood-vessels, and by varying the diameter of these capillaries another method of regulating body-temperature is possible (see p. 101).

The *sense-organs of touch*—warmth, cold, pain, and touch—are just below the outer skin. These sense-organs are the endings of nerves which carry sensations to the central nervous system—the brain and spinal cord.

The innermost layer of skin, which contains deposits of *fat*—a bad conductor of heat—reduces loss of heat from the body. This layer of fat is particularly important to mammals that live in water. Whales, for example, whose body-temperature is much the same as our own, have a thick, uniform layer of fat (blubber) to prevent loss of heat to the surrounding cold water.

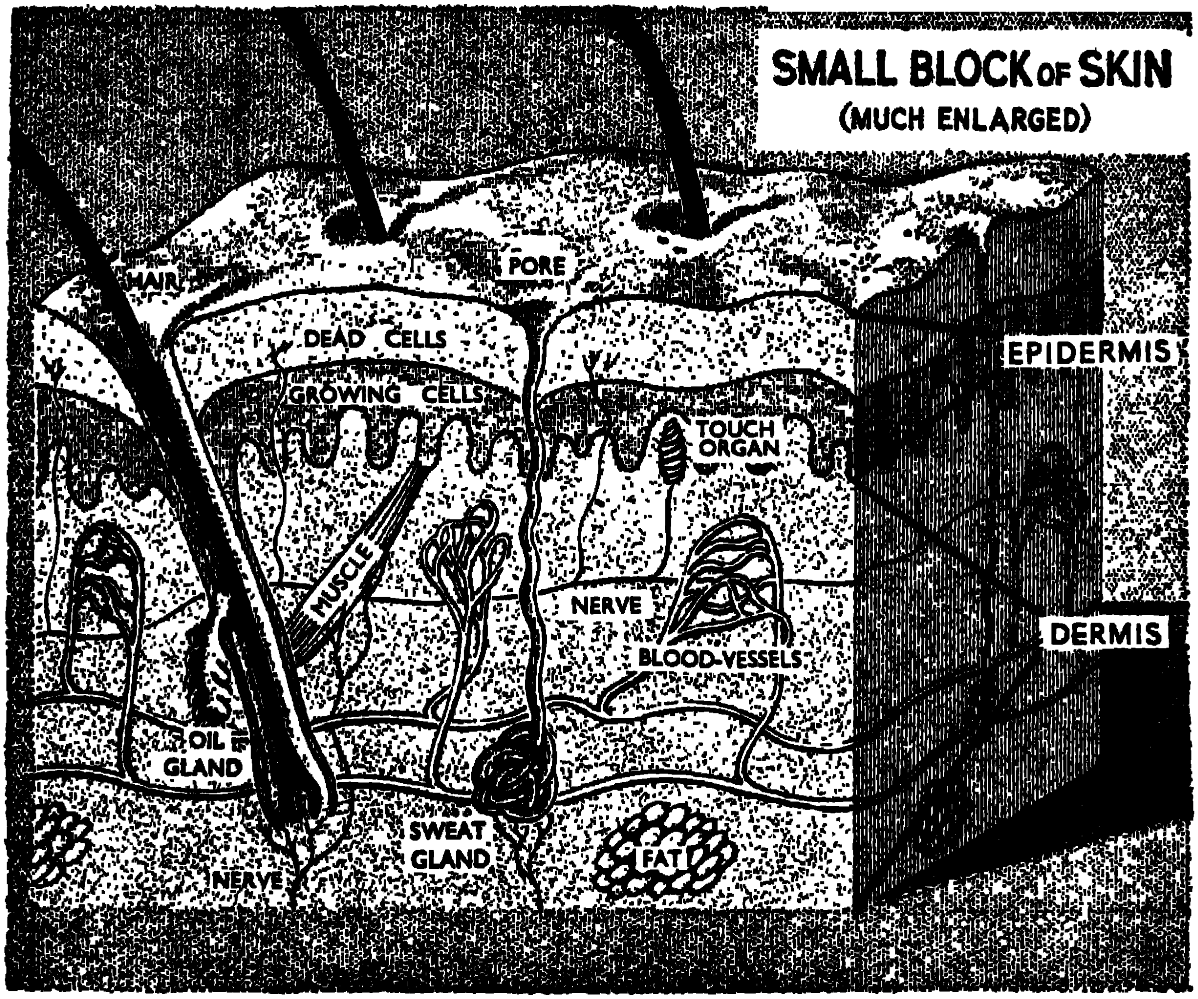


FIG. 20.—Skin structure (diagrammatic)

THE NERVOUS SYSTEM

One of the most important differences between living and non-living things is that living things are *active* and can adapt their behaviour to changes in their surroundings. In the animal world, this *response to an* *external stimulus* in higher animals has to be more rapid than in plants, and this need is met by their complicated *nervous system.*

A mammal moves by means of muscles attached to its jointed bones. These muscles are very numerous and very complicated in their action. For example, in our own body, when we walk, from the time we press on the ground with our right foot until we press on the ground with our left foot, half a second later, we use about 300 muscles. In a higher animal, provided with hundreds of different muscles, all able to pull in various directions, it is clearly necessary to direct and control them so that they all work in the right way and at the right time. This is the work of the nervous system, consisting of the *nerves*, the *spinal cord*, and the *brain* (see Fig. 21). The brain and the spinal cord form the central part of the nervous system. The work of the nerves is to carry impulses from the sense-organs to this *central nervous system* and then from the central nervous system to the various muscles and glands of the body.

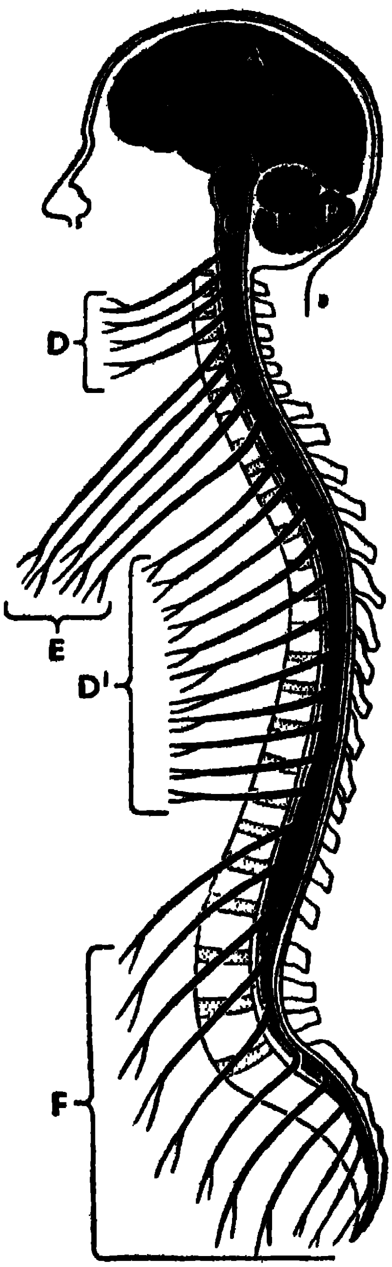


FIG. 21—The central nervous system and main nerves (diagrammatic)

A, B, C—Cerebrum, cerebellum and spinal cord, respectively, forming central nervous system.
D, D^1, E, F. Main nerves—(D) supplying left side of the neck; (D^1) supplying left side of thorax and abdomen; (E, F) to arm and leg respectively.

The nerves

A nerve carries impulses. This is its only function. The nerves in an animal's body correspond to the wires which run from house to house in a telephone system. The nerves carry impulses from the sense-organs *inwards* to the brain and the spinal cord, and they also carry impulses from this central nervous system *outwards* to the muscles. The nerves which carry impulses *inwards* from the sense-organs are called *sensory nerve-fibres* and they give rise to the *sensations* of sight, hearing, taste, smell, touch, temperature, pain, movement, and balance. The nerves which carry impulses *outwards* to the muscles and make them move are called *motor nerve-fibres.* The nerves which one sees as white threads in a dissection are bundles of nerve-fibres, and they may contain both sensory and motor nerve-fibres lying side by side. In such cases, we speak of *mixed nerves*, because some of the fibres give rise to sensations and others control muscle movements.

In the same way as the nerves correspond to the street-wires in a telephone system, the central nervous system (brain and spinal cord) corresponds to the central telephone exchange. This central nervous system sorts out messages received from the sensory nerves and sends out suitable responses along the motor nerves to the muscles. These responses which take place through the central nervous system are of two kinds: (*a*) *voluntary actions* and (*b*) *reflex actions* (or involuntary actions).

Voluntary actions are controlled by the will. Reflex actions are unconscious responses to stimuli.

Reflex action

With practice and training, many voluntary actions become reflex actions. In other words, we develop a *habit*. For example, when learning to shoot with a rifle, we have to make a special effort of the will to keep the left eye closed while we take aim with the right eye, but after a time it is closed *automatically*, and unconsciously, as soon as the rifle is brought into the aiming position. Similarly, when one learns to swim, every new movement of the limbs requires a special effort of the will, but once one has *learnt* the strokes, the muscles carry out the necessary movements automatically, without any conscious effort of the will. In the same way, when learning to ride a bicycle, it is only by voluntary action that one turns the front wheel so as to avoid falling off. When this action becomes automatic, we have 'learnt to ride'.

The simplest response of an animal to an external stimulus is a reflex. As an example of a reflex, consider what happens when you sit down by accident on a sharp, pointed object. You jump up immediately, without having to think about it. This is a reflex action, and like most other reflexes, it is a *protective response*, since the body would have been hurt if it had been left sitting on the sharp object. Although the complete reflex occupied only a fraction of a second, *three parts of the nervous system are concerned:* (*a*) *a sensory nerve*, (*b*) *the spinal cord*, and (*c*) *a motor-nerve.* First of all, sensitive nerve-endings in the touch-organs of the skin are affected by the pain-stimulus and send a message along *sensory* nerve fibres to the spinal cord. Then a message is sent out by the nerve-cells of the spinal cord along the *motor* nerve-fibres to the voluntary muscles concerned, which contract and move the body away from the cause of the pain-stimulus. The inward passage of the sensation and outward passage of the stimulus to the muscles together form a *reflex arc* or curve, and this is the path of a *simple involuntary spinal reflex* (see Fig. 22A).

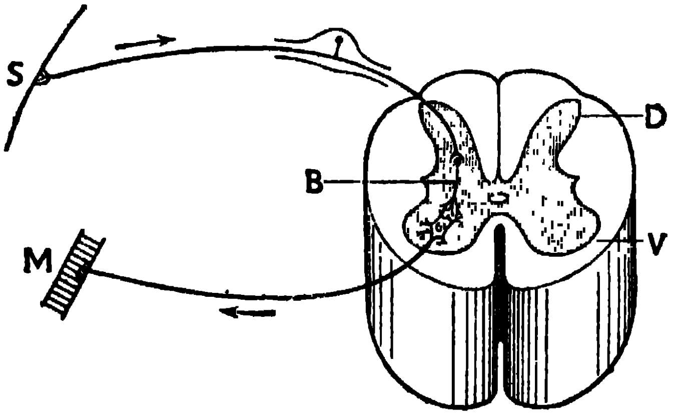


FIG. 22A.—Diagrammatic section across spinal cord, showing grey matter (nerve-cells) and white matter (nerve-fibres), and the path of a simple involuntary spinal reflex

S—sensitive nerve-ending in skin. M—muscle at outer end of motor-nerve. D—dorsal horn of grey matter. V—ventral horn of grey matter. B—inter-communicating branch between nerve-cells in spinal cord.

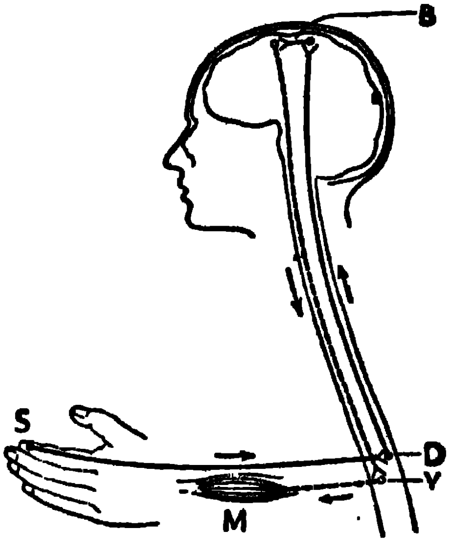


FIG. 22B.—Simplified diagram showing path of modified reflex, controlled by brain

S—sensitive nerve-ending in skin. M—muscle at outer end of motor-nerve. D—nerve-cell in dorsal horn of grey matter in spinal cord. Y—nerve-cell in ventral horn of grey matter in spinal cord. B—inter-communicating branch between nerve-cells in grey matter of brain.

Voluntary action

In 'higher' animals, such simple *spinal reflexes* are usually only the first stage in the animal's reaction to a stimulus. The message from the touch-organs in the skin finally reaches the *brain* and gives rise to sensations of touch and pain. In some cases, the brain sends a message to stop the reflex action. For example, if you pick up a hot object in the dark, your simple protective reflex response to the pain-stimulus will be to drop it and your brain does not interfere. But suppose you are doing an experiment in the laboratory and have already weighed a crucible very carefully. Then, after heating it you forget that the crucible is still hot and pick it up with your fingers. Your automatic reflex is to drop it; but unless the crucible is very hot, you will make an effort of the will and put the crucible down gently so as to avoid having to start the experiment over again. That is, in a fraction of a second, by reasoning, you decide that it is better to suffer temporary discomfort rather than give yourself half an hour's extra work. In this case, the simple reflex has been controlled and modified by the *brain.* The nerve-impulse from the finger-tips has not been dealt with merely in the spinal cord but has travelled on up to the brain (see Fig. 22B). *Simple reflex actions have their centre in the spinal cord or in the hind-brain. Voluntary actions have their centre in the fore-brain.*

Like reflex actions, voluntary actions involve receiving a stimulus by a sense-organ and the transmission of the impulse inwards to the central nervous system and outwards again to the muscles, but *in a voluntary action the path of the nervous impulse is much longer than in the case of a simple reflex action,* and there is often some delay between receiving the external stimulus and the voluntary action that results from it. In practice, simple reflexes are uncommon, and the nervous impulse which travels to the spinal cord or to the hind-brain is usually transmitted to the fore-brain as well, and this part of the brain controls and modifies the simple reflex action.

The nerves from the eyes, ears, mouth, nose, face, neck, and some of the internal organs, however, run directly to the brain, independently of the spinal cord.

The central nervous system

The *central nervous system* consists of the *spinal cord* and the *brain.* The brain is the enlarged and specialized anterior end of the spinal cord, so we shall describe the spinal cord first, before going on to the brain, which is more complicated.

The Spinal Cord—The spinal cord, which runs down the middle of the backbone, is made up of *nerve-fibres* (white) and *nerve-cells* (grey). The white nerve-fibres lie round the outside of the spinal cord, and the grey nerve-cells are massed together in the middle. In cross-section, the 'grey matter' is shaped rather like an H (see Fig. 22A). The *sensory nerve-fibres,* carrying impulses *inwards,* lead into the two dorsal horns of the H-shaped grey matter, while the *motor nerve-fibres,* carrying impulses *outwards,* arise from the two ventral horns of the H. Running down the middle of the spinal cord is the *central canal,* containing liquid. The spinal cord is divided into right and left halves by two deep grooves in its dorsal and ventral surfaces.

The Brain—The spinal cord becomes larger and more complex at its anterior end (see Fig. 23). As the spinal cord enters the head, it expands to form the *spinal bulb* (or *medulla*). This part of the brain controls the involuntary movements of the body, e.g. breathing, heart-beat, and the movements of the food-canal during digestion. Above the spinal bulb is the '*little brain*' (or *cerebellum*)—a swelling whose surface appears to be folded. The little brain sees that all the body-movements are in step with each other. It is responsible for *balancing* the body-movements, e.g. if the '*big brain*' (or *cerebrum*) orders a movement of one limb, the little brain automatically sends out impulses which cause movements of other parts of the body so that it does not overbalance.

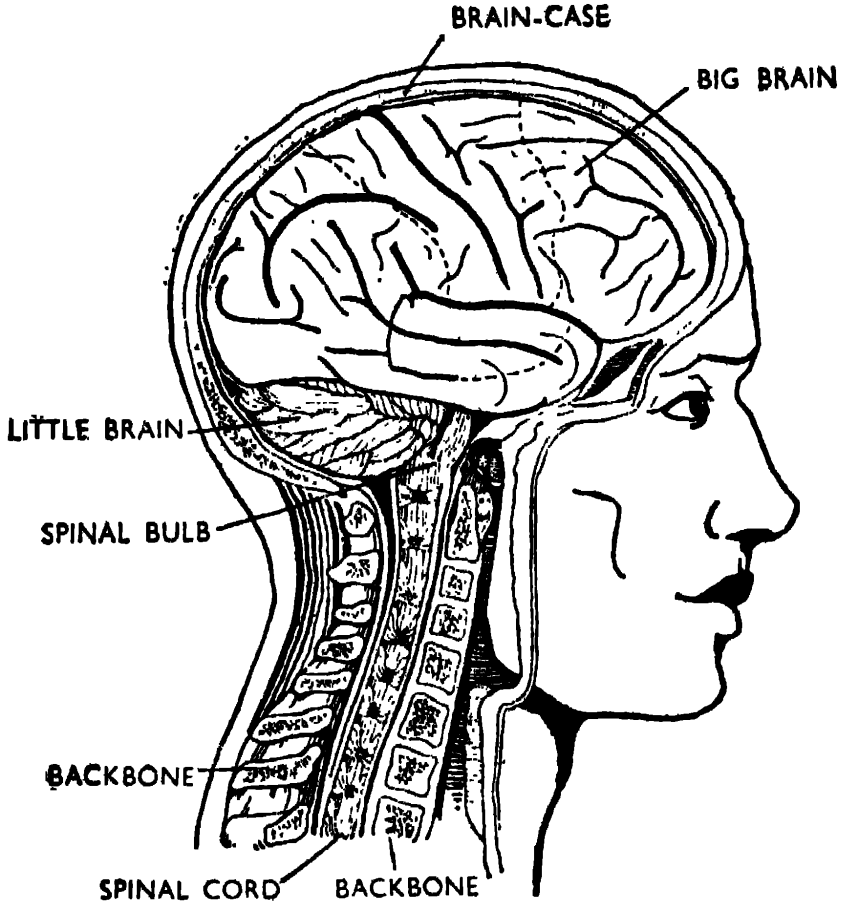


FIG. 23.—Diagram of human brain and part of spinal cord

(*After Huxley and Starr*)

Anterior to the little brain is the *big brain*, which forms the largest part of the brain in mammals. The big brain is the centre of all conscious, voluntary actions and sensations, e.g. will, memory, reasoning, and feeling.

In the brain, most of the nerve-*cells* (the grey matter) lie on the outside of the nerve-*fibres* (the white matter), the converse of the arrangement in the spinal cord. Since capacity for conscious voluntary actions, e.g. will, memory, reasoning, sensation, and feeling, depends on the number of nerve-*cells* present in the brain, it is clearly an advantage to have the grey matter spread out in a thin layer (0·1 in. thick in Man) over the *outside* of the brain, where it can continue to grow and extend without any pressure from surrounding parts. In the highest animals, the area of grey matter is still further increased by a folding of the surface of the big brain.

In proportion to his size, Man has the largest and most folded big brain of any animal. Man is the most *intelligent* animal. He can *reason* or 'think things out', he can ask questions, and he can decide between right and wrong. In the lower vertebrates, which are much less intelligent and which give no evidence of having the power of reasoning, the grey matter of the big brain is much less well developed.

CHAPTER 2

FOOD AND NUTRITION

Man's principal material needs are *food*, *clothing*, and *shelter*. In warm climates, however, he can be healthy and happy with very little clothing and with only light shelter from the weather. But whatever his climate and surroundings, *he must have food.* So the first concern of Man (like all other animals) is to get sufficient suitable food, (*a*) *to supply energy which can be set free by oxidation* (part of this energy being converted into *heat*, which keeps the body warm; and part into *energy of movement*), (*b*) *to provide the raw materials for growth, repair, and reproduction*, and (*c*) *to regulate the healthy working of the body* and so *protect* it from ill-health and disease.

Food-production, therefore, is the most important of all human occupations and it is estimated that this is the main activity of about 70 per cent. of the world's population. In fact, for the majority of mankind, half the struggle of life is a struggle for *food.*

Good food is the greatest single factor in securing good health, for although poor food may keep people alive they must have good food in order to live *well.* If anyone is starved of food for long enough, he will die. If his food lacks quantity or quality he cannot enjoy full health. So better feeding is the most promising way to improve health and happiness in backward communities handicapped by widespread ill-health and disease.

Poor feeding causes poor health in three main ways: *Through the food being* (i) *insufficient in quantity*, (ii) *unbalanced in its constituents*, and (iii) *contaminated by harmful organisms and substances*. Before studying how *food-values* are described in scientific terms and measured in scientific units we must get some idea of the various *kinds* of foodstuffs.

THE CLASSIFICATION OF FOODS

Although different animals feed on many different kinds of foodstuffs, these can all be classified scientifically in two main ways: (*a*) according to their *chemical composition*, or (*b*) according to their special *function* in the working of the body.

The chemical classification divides animal foodstuffs into six main groups: (i) *carbohydrates*, (ii) *fats*, (iii) *proteins*, (iv) *mineral salts*, (v) *water*, and (vi) *vitamins*. Of these types of foodstuffs, *carbohydrates and fats are energy-yielding foods, proteins are body-building foods*, while *vitamins and certain mineral salts are sometimes described as protective foods.*

Carbohydrates

The commonest carbohydrates used for human food are *starch* and *sugar*, both of which are formed and stored by green plants. Examples of foodstuffs rich in carbohydrates are rice, wheat-flour, cane-sugar, potatoes and similar root-vegetables.

Chemically, carbohydrates are compounds of carbon, hydrogen, and oxygen, with their hydrogen and oxygen present in the same relative proportions as in water, i.e. 2 atoms of hydrogen to every atom of oxygen. The carbohydrates can be further classified into (i) *sugars*, (ii) *starches*, and (iii) *celluloses*, or, for chemical purposes, into (*a*) *simple sugars* (e.g. glucose and fructose), (*b*) *complex sugars* (e.g. sucrose, lactose, and maltose), and (*c*) *complex carbohydrates* (e.g. starch, dextrin, glycogen, and cellulose). (See pp. 249–51 for experiments on carbohydrates.)

Complex sugars

Ordinary household 'sugar' is *sucrose* (or *cane-sugar*) and it is mostly obtained from the sugar-cane, the sugar-beet, or the sugar-palm. Sugar-cane is crushed between iron rollers to extract the cane-juice. This juice, which contains about 20 per cent. of sugar, is then purified, filtered, and evaporated, and the crystals of 'raw', brown sugar are removed from the liquid residue (treacle or molasses). This crude brown sugar is refined by melting and decolorizing with charcoal, and it is then evaporated at a low temperature to produce the familiar white crystals used in the household. Sugar-beets are crushed to a pulp and the sugar is extracted with water, the solution being purified and evaporated by processes similar to those used in manufacturing sugar from the sugar-cane. Sugar is also obtained from sugar-palms by tapping the flower-shoot and evaporating the sap that flows out. The purified product, in each case, is the same chemical compound, *sucrose.*

Sucrose (or cane-sugar) is a complex sugar because *it can be split up into two simple sugars* by the action of special *enzymes*,[1] yielding a mixture of *glucose* and *fructose* called *invert sugar*. *Honey* is a natural form of invert sugar. *Jam* also contains a large proportion of invert sugar.

---

[1] Many chemical changes which take place very slowly when left to themselves can be to proceed much more rapidly when a small quantity of a suitable *catalyst* is added. *Enzymes are organic catalysts produced by living cells.*

Lactose (or *milk-sugar*), which is present in cows' milk to the extent of about 5 per cent., is another complex sugar. Like sucrose, lactose can be split up by an enzyme into two simple sugars, one of them being *glucose*.

Maltose (or *malt-sugar*), another complex sugar, is formed in the mouth when an enzyme in the saliva begins to act upon starch in the food. Like sucrose and lactose, maltose is readily split up by a suitable enzyme into a simpler sugar—*glucose*.

Simple sugars

Glucose (*grape-sugar* or *dextrose*) is the commonest and most important of the simple sugars. It is probably the first carbohydrate formed during photo-synthesis in green plants and it is always present in plant-cells, where it may be used in building up proteins and also in respiration. It is found in quantity in some fruits, e.g. grapes (raisins—dried grapes—contain crystals of glucose). The blood always contains small quantities of glucose, and this is carried in the blood to the body-cells where it is oxidized, yielding *energy*. Commercially, glucose is made by boiling starch with very dilute acids under pressure. The product provides a cheap sweetening agent used in making jams and sweets.

Fructose is a closely related simple sugar, common in fruits and in nectar from flowers.

The simple sugars are sweet, crystalline substances, very soluble in water. They cannot be split up into simpler carbohydrates, but they are readily oxidized to yield energy.

Complex carbohydrates

Starch is one of the commonest and most important of the complex carbohydrates. It is the chief reserve food material of plants, in which carbohydrates, made in the leaf as *glucose*, are transported as sucrose and stored in the form of *insoluble starch*. Starch grains are quite insoluble in water until they have been heated or subjected to enzyme action. Then they break down into smaller particles, which become *suspended* in water to form a cloudy paste (but *not* a true solution). If this paste is heated with dilute acid or acted upon by a suitable enzyme, the starch is broken down to sugar.

Dextrin is another complex carbohydrate formed when starch is heated to about 200° C. (e.g. in baking). It is also formed in the mouth as an intermediate product when the saliva begins to act on starchy food.

Glycogen (sometimes called *animal starch*) is the commonest carbohydrate reserve in animals, where it is found mainly in the liver and the muscles, e.g. a well-fed man has about 200 g. of glycogen in his liver and about 350 g. in his muscles.

Cellulose is the name given to a number of complex carbohydrates that form the cell-walls of plants. Cotton, linen, and filter-paper are nearly pure cellulose. Cellulose, in its different forms, is of very great importance to Man. It is one of the main constituents of *wood*, which is used in enormous quantities for a great variety of purposes. Paper, too, is mainly cellulose.

Fats

Many plants store *oil* as a reserve food material instead of the more usual starch, e.g. coconut-oil, palm-oil, soya-bean-oil, olive-oil, etc. Fishes and other 'cold-blooded' sea-animals also produce oils, e.g. cod-liver-oil, shark-liver-oil, etc., while 'warm-blooded' animals store similar substances with higher melting-points, which are solids at ordinary temperatures. These solid oils we call *fats*. (Coconut-oil and palm-oil are *liquid oils* in the tropics but are *solid fats* in colder regions.)

Such oils and fats are *not* hydrocarbons [1] like petroleum, but they contain the chemical elements *carbon, hydrogen, and oxygen*. They are *not*, however, carbohydrates, since the hydrogen and oxygen are not present in the same proportions as in water. There is much less oxygen in proportion to hydrogen in fats than there is in carbohydrates. For this reason, oils and fats require more oxidation than do carbohydrates (weight for weight) and therefore yield more energy.

Meat-fat, egg-yolk, milk-fat (butter or ghee), nuts, and vegetable oils are common sources of fat for food.

Both carbohydrates and fats are readily burnt or oxidized, producing carbon dioxide and water, and setting free *energy*; in fact, *these two classes of food materials supply most of the chemical energy which the body transforms into muscular WORK and into body-HEAT*. Fats, when burnt, produce nearly twice as much heat as the same weight of carbohydrates and are, therefore, more important foods in cold countries than in hot. A well-balanced diet contains much less fat than carbohydrate, particularly in a hot climate.

Fats are 'organic salts', being compounds of the 'organic base', *glycerine*, with *fatty acids*, e.g. olive-oil is mainly composed of the *glyceride* of *oleic acid*; palm-oil is mainly the glyceride of *palmitic acid*; mutton-fat contains the glyceride of *stearic acid*, and butter is mainly the glyceride of *butyric acid*. The *fat-splitting enzymes* split fats into glycerine and fatty acid. A similar decomposition is brought about when fats are boiled with caustic soda (sodium hydroxide), but the fatty acid at once combines with the *alkali* to form *soap*. (Fat + alkali = soap + glycerine.) *Only sodium and potassium soaps are soluble in water*. The stearates, oleates, and palmitates of the other metals are all *insoluble soaps*. Hence, when soap is added to *hard water* (containing calcium, magnesium, or iron compounds) no lather is produced at first, but only a surface layer (or scum) consisting of calcium, magnesium, or iron soaps, which are insoluble in water. Hence the amount of soap required to produce a permanent lather measures the *hardness of a sample of water*. (See pp. 251–2 and 255–6 for experiments.)

---

[1] Hydrocarbons are compounds of hydrogen and carbon only.

Proteins

Proteins are the third great class of chemical compounds present in plants and animals along with carbohydrates and fats. Seeds are always rich in proteins, and small quantities of proteins are found in roots, stems and leaves. The bodies of animals always contain a larger proportion of protein than is found in plants. These animal proteins are all obtained, in the first place, from plant proteins. Plants synthesize their protein from simpler materials like sugars, nitrates, and ammonium compounds.

Proteins always contain carbon, hydrogen, and oxygen, *together with nitrogen*. Nearly all proteins also contain *sulphur*, while many of them contain *phosphorus* as well. Proteins are some of the most complex of all chemical compounds.

When proteins are boiled with acids for a long time, they are split up into simpler compounds called *amino-acids*; in fact a protein molecule appears to consist of a long chain of amino-acids. There may be 50 to 500 links in this chain, and each link is an amino-acid molecule. These 'amino-acid links' can be 'unlocked' by heating with acids or by the action of *protein-splitting enzymes* (just as the complex sugars can be split up into simpler sugars). Or, to put it another way, the amino-acids are the units, or 'bricks', from which the proteins are built. About 24 of these amino-acids are found in natural proteins, and one protein differs from another in the number and arrangement of its constituent amino-acids.

This has an important bearing on the use of proteins as food. The proteins eaten by animals are seldom the same as those in the animal's body-tissues, and the digestion of proteins serves to split the food-proteins into their constituent amino-acids before they enter the blood-stream. The body-cells then select the ones that can be built up into the body-protein they need for growth and repair. (See p. 252 for tests.)

Mineral salts

Animal food must include *salts* of the elements sodium, potassium, calcium, iron, chlorine, phosphorus, and iodine. The blood, for example, contains common salt (sodium chloride) and iron compounds, while bones and teeth contain calcium phosphate and calcium carbonate. Only small quantities of these salts are required, and most natural animal and vegetable foodstuffs contain sufficient quantities. The only elements ever likely to be lacking in human diet are *calcium*, *phosphorus*, *iron*, and *iodine*. We shall discuss such deficiencies later. Under normal conditions, common salt is the only mineral salt which it is necessary to add regularly to human food.

Water

Water is essential to life and all living matter contains a large proportion of water, e.g. about 70 per cent. of the human body is water. Men have lived without solid food for 20–30 days, but they had to drink water during this period. Water is so very important because all the chemical changes which take place in the body do so *in dilute solutions*. Water also plays an important part in *excretion* and (in 'warm-blooded' animals) in regulating the temperature of the body.

Vitamins

Vitamins are substances present in extremely small amounts in fresh foodstuffs and they are essential for health. Green vegetables, fresh fruit, milk, butter, eggs, and the outer layers of food-grains, supply the vitamins essential to Man. It is only when these foods cannot be obtained fresh and in sufficient quantity that special vitamin preparations are necessary. These important *accessory food substances* will be discussed in more detail later in this chapter.

FOOD AND ENERGY

By far the greater part of your food is oxidized to provide you with energy. Carbohydrates such as starch and sugar are the cheapest source of this energy and the most easily oxidized. Fats, also, are valuable sources of energy (supplying about twice as much energy as the same weight of carbohydrate), but this energy is not set free so readily as from carbohydrates. Carbohydrates and fats, therefore, are the *energy-giving foods*.

Proteins and mineral salts provide the raw material for growth, repair and reproduction, i.e. they are the *body-building foods* (although any excess of protein over that required immediately for body-building can be oxidized to yield energy).

One of the fundamental laws of science states that '*Energy can be neither created nor destroyed*,' i.e. although energy can be transformed from one form to another, the total amount of energy involved in the conversion remains unchanged. This *Law of Conservation of Energy* is the basis of *physics*, but it also applies to all the living processes taking place in plants and animals. In the case of animals, the truth of this has been tested experimentally by comparing the amount of energy an animal produces in a given period with the amount of energy obtainable from the animal's food over the same period. Animals have been given a measured quantity of food and kept in specially constructed *calorimeters* [1] for several hours, and the amount of heat-energy produced has been carefully measured (see Fig. 24). The same amount of the same kind of food has then been burnt in oxygen in another type of calorimeter and its *heat of combustion*

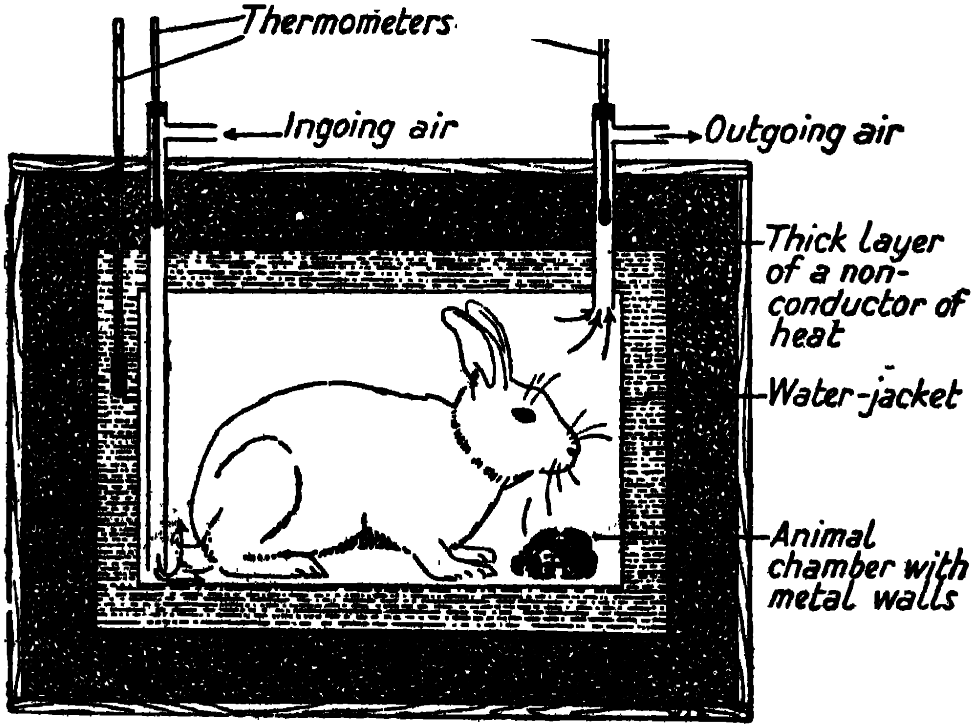

Thermometers
Ingoing air
Outgoing air
Thick layer of a non-conductor of heat
Water-jacket
Animal chamber with metal walls

FIG. 24.—Animal calorimeter

---

[1] See p. 274: The Measurement of Heat Energy.

has been found. In such experiments (provided that the animal neither gains nor loses weight while it is in the calorimeter) it is always found that *the same amount of food produces the same amount of heat-energy whether it is burnt rapidly in oxygen or oxidized slowly in an animal's body.* An animal, therefore, is just as much a *heat-engine* as a petrol-engine is. A motor-engine gets its energy from the rapid oxidation of petrol, while the animal gets its energy from the slow oxidation of food-substances in its body-cells with the aid of *enzymes* (see p. 79).

Energy output and food requirements

Since the Law of Conservation of Energy applies to animals, if we know how much energy an animal produces (as heat and work) in a day, we can find out how much food it must eat in order to supply this amount of energy. A man's energy-output depends on the kind of physical activity in which he is engaged, on the size of his body, and on the climate around him. It is important to realize, however, that some muscles are always working, even when a man is 'resting'; for example, his heart-muscle and the muscles concerned with breathing-movements are *doing work* even during sleep.

When lying down, completely relaxed and at rest (but still awake), *a man produces, every hour, about* 1 *Calorie* [1] *of heat per kilogram of body-weight.* (It is easy to remember *one Calorie per Kilogram per hour.*) So if you weigh 50 Kg. (= 110 lb. or nearly 8 stone) you will produce about 1,200 Cal. of heat while resting completely for 24 hours. This will be your *basic energy requirement.* Any additional activity will require additional energy, e.g. merely sitting upright will increase this basic requirement by about 40 per cent.; standing will need an increase of 60 per cent., as shown below.

Activity	Approx. Energy Requirement per Kg. of body-weight per hour (Cal./Kg./hr.)	Approx. Energy Requirement per hour for men weighing—	
		50 Kg. (= 110 lb.) Calories	70 Kg. (= 154 lb.) Calories
At rest, lying down	1·0	50	70
Sitting upright	+ 0·4 1·4	70	98
Standing straight up	+ 0·6 1·6	80	112
Slow walking	+ 1·0 2·0	100	140
Moderate exercise	+ 3·0 4·0	200	280
Severe exercise	+ 5·5 6·5	325	455
Sleeping	– 0·1 0·9	45	63

---

[1] See p. 274: The Measurement of Heat Energy.

Hence, if you know how long you devote to various kinds of bodily activity during the 24 hours you can calculate how many energy-units you need from your daily food. Here are two typical examples:

Activity	Duration in hours	Calories required by 50 Kg./110 lb. Student
Sleeping	9	9 × 0·9 × 50 = 405
Sitting	8	8 × 1·4 × 50 = 560
Standing	2	2 × 1·6 × 50 = 160
Walking	2	2 × 2·0 × 50 = 200
Moderate exercise	2	2 × 4·0 × 50 = 400
Severe exercise	1	1 × 6·5 × 50 = 325
	24	2050

Activity	Duration in hours	Calories required by 70 Kg./154 lb. Labourer
Sleeping	8	8 × 0·9 × 70 = 504
Sitting	4	4 × 1·4 × 70 = 392
Standing	4	4 × 1·6 × 70 = 448
Walking	2	2 × 2·0 × 70 = 280
Moderate exercise	2	2 × 4·0 × 70 = 560
Severe exercise	4	4 × 6·5 × 70 = 1820
	24	4004

These two examples will help you to appreciate that energy-output (and food requirements) differ widely for different individuals, depending on their body-weight and on their occupation. Individuals also differ in the efficiency of their digestive processes, some people absorbing a larger proportion of their food than others. (The 'average' figures given below include an extra allowance of 10 per cent. for that part of the food which is not digested or absorbed.) Climate is another important factor since in warm climates less energy (roughly 10 per cent. of the total requirement) is needed to maintain body-temperature. Human females, also, utilize a larger proportion of available energy than males. On the average, a woman needs only about 83 per cent. as much energy as a man of the same weight doing similar work, i.e. about one-sixth less. In view of these very wide variations in the energy-output and food requirements of different individuals, any figures for 'the average man's' requirements can be only a very rough general guide. If you bear this in mind when considering the recommendations of nutrition experts and advisory bodies, then you will be able to adjust these 'average' figures to fit special classes and individual cases.

Body-weight and food requirements

The simplest test of adequate nutrition in an adult is whether the body-weight remains steady. Too few Calories of food-energy will result either in loss of weight or in inability to do hard work. Too many Calories, adequately absorbed, will result in an increase in body-weight, the extra energy-yielding food being stored mainly as fat. The human body is very *adaptable* and it adjusts itself very efficiently to changes of diet, e.g. when Calorie-intake is less than energy-output over a long period the body loses weight until the two balance. In such cases, body-fat is used up before muscle, and when muscle has to be utilized for this purpose it is the less important muscles that lose most weight, e.g. the biceps and calf muscles become greatly reduced before the heart-muscle begins to lose weight. So loss of weight under conditions of prolonged food-shortage is usually the body's natural adjustment to the changed conditions and not the result of disease. On the other hand, marked loss of weight in a person well supplied with food is usually a danger-signal calling for investigation by a doctor. Excessive fatness, when not obviously due to habitual over-eating, may also call for medical advice.

Energy values of foods

We shall now consider the 'energy-values' of the various kinds of foodstuffs. Of the six chemical classes of foodstuffs—carbohydrates, fats, proteins, water, salts, and vitamins—only the first three can supply energy on oxidation. The approximate energy-values of carbohydrates, fats, and proteins are:

One gram of a carbohydrate yields about 4 *Calories on oxidation.*
One gram of a fat yields about 9 *Calories on oxidation.*
One gram of a protein yields about 4 *Calories when partly oxidized.*

It is clear that the daily requirement of Calories of food-energy could be built up from many different proportions of carbohydrate, fat, and protein. For example, a well-balanced diet for a cool climate might contain

500 grams of *carbohydrate*,	yielding	2,000 Calories,
100 grams of *fat*,	yielding	900 Calories,
100 grams of *protein*,	yielding	400 Calories,

making a total of 3,300 Calories (which is about the daily requirement for a 70 Kg. man doing six hours of moderate muscular work in a cool climate).

Food tables[1] show the relative proportion of the various constituents in everyday foodstuffs as determined by *chemical analysis*; also their relative *calorific value*. With the help of such food-tables it is possible to calculate the food-value of any particular diet. The following example has been worked out in this way.[2]

Rice	10 ounces	(284 g.)	1,012 Calories
Millet	5 „	(142 g.)	455 „
Milk	8 „	(227 g.)	136 „
Pulses	3 „	(85 g.)	224 „
Non-leafy Vegetables	6 „	(170 g.)	236 „
Green Leafy Vegetables	4 „	(113 g.)	36 „
Fats and Oils	2 „	(57 g.)	475 „
Fruits	2 „	(57 g.)	26 „
			2,600

This is a good example of a *well-balanced diet* supplying enough energy for a 60 Kg. man doing six hours of 'moderate work' in a warm climate.

It has been suggested by nutrition experts that the relative proportions of the various foodstuffs in the diet should be such that *about two-thirds of the energy-requirement is provided by carbohydrates, one-sixth by fats, and one-sixth by proteins* (*at least one-fifth of this protein being animal protein and the rest vegetable protein*), but these proportions can be varied somewhat to suit special conditions and the special needs of different people, so long as the following principles are kept in mind:

(*a*) *There must always be enough protein for growth and repair.*[3]
(*b*) *Hard muscular work requires an increased proportion of carbohydrates.*
(c) *Under cold conditions, an increased proportion of fat will provide extra heat.*

---

[1] For example, B. S. Platt, *Tables of Representative Values of Foods Commonly Used in Tropical Countries* (Her Majesty's Stationery Office). See also p. 231.

[2] Health Bulletin No. 23, *The Nutritive Value of Indian Foods and the Planning of Satisfactory Diets*, prepared by the Nutrition Research Laboratories, Coonoor, and published by the Manager of Publications, Delhi.

[3] One gram of dry protein per kilogram of body-weight, i.e. one-thousandth part of the body-weight, per day, is a rough, but safe, guide for adults; growing children, however, need more than this, e.g. up to 2 g. per kilogram of body-weight.

Diet planning

Ill-health is often caused by badly-planned and badly-balanced diets. Foodstuffs differ in value as sources of carbohydrates, fats, proteins, mineral salts, and vitamins; hence the diet should be *mixed*, i.e. several different kinds of carbohydrate food should be eaten, several different kinds of fat, several different protein foods, and so on.

Carbohydrate foods are nearly always the cheapest and the most satisfying, e.g. rice, wheat-flour, potatoes (English potatoes and sweet potatoes), cassava (tapioca), yams and similar root-vegetables, maize and other food-grains, and sugar (cane-sugar, beet-sugar, and palm-sugar). Fats can be obtained from both animal and vegetable sources, but animal fats are the more easily digested. Nearly all meat contains some fat. Other sources of animal fat are milk and, of course, milk-fat (in the form of butter or ghee), which is the most easily digested of all fats. Pea-nuts (ground-nuts), soya-beans, palm-oil, and coconuts all supply vegetable oils and fats that can be used for food.

All proteins are not of equal food-value, because they do not all contain every essential *amino-acid* in suitable proportions. A protein that contains all the required amino-acids in the proportions needed to support human life is called a '*complete*' (or '*first-class*') protein, or it is said to be a protein of *good biological value*. A protein that does *not* contain all the essential amino-acids, or which contains them in unsuitable proportions, is called an '*incomplete*' (or '*second-class*') protein, or it is said to be a protein of *poor biological value*. All animal proteins (except gelatine) are 'complete' proteins, while plant proteins are all 'incomplete'. Examples of animal protein are lean meat (beef, mutton, fish, bird), eggs, milk, and cheese. These are all expensive foods. Examples of foodstuffs supplying vegetable proteins are the various kinds of *legumes* (pod-bearing plants, e.g. peas, beans, grams, lentils, soya-beans). These plant proteins are cheaper to buy than animal proteins. The table on p. 241 shows the comparative food-value of some common foods that contain protein.

The various materials needed for a healthy diet make up a long list, and we are more likely to get all the things we need if we eat different foodstuffs at different meals and on different days, i.e. by '*mixing our diet*'. A mixed diet of protein foods is particularly important, since a mixture of a 'complete' and an 'incomplete' protein is of much greater food-value than the same quantity of either eaten separately; hence you should *mix your proteins* whenever possible.

Requirements of mineral salts

It has been estimated that a man's body (weighing about 70 Kg. = 154 lb.) contains about 1,000 g. of calcium, 700 g. of phosphorus, 250 g. of potassium, 175 g. of sulphur, 100 g. of sodium, 100 g. of chlorine, 35 g. of magnesium, 3 g. of iron, and smaller quantities of manganese and iodine. A healthy and active man excretes from 20–30 g. of mineral salts in his urine and faeces every day, and these have to be replaced from his food. For practical purposes, the mineral salts which are most likely to be needed in human diet are compounds of *calcium*, *phosphorus*, *iron*, and *iodine*.

Most of the calcium and the phosphorus in the body are combined together as calcium phosphate in the bones and teeth, but there is some loss of both elements during excretion and this loss must be replaced. Growing children (who are building up their bones and teeth) require about 1 g. of calcium per day; adults require a little less. Foodstuffs which supply *calcium* are milk, cheese, egg-yolk, green vegetables, grams, lentils, ground-nuts, and soya-beans. In places where the drinking-water is 'hard', some calcium is also obtained in this way (see also p. 240).

The daily *phosphorus* requirement is about 1 g., and the chief sources of this element are milk, cheese, and egg-yolk (these three foodstuffs also supply calcium), meat (especially liver and kidney), fish, nuts, legumes, and food-grains (see also p. 241).

About 0·01–0·02 g. of *iron* is required daily, and this element is essential for the formation of *haemoglobin* in the red blood-cells. Foodstuffs which supply iron are sea-fish, egg-yolk, green vegetables, brown rice and whole-grain cereals, nuts, peas, and beans. Not all the iron present in the food can be absorbed, especially when there is an excess of phosphorus to combine with the iron and render it insoluble and therefore unavailable. So it is better to have more calcium than phosphorus in the diet; in fact, calcium carbonate is sometimes added to wheat-flour in order to get a proper ratio between phosphorus and calcium in the diet and thus ensure effective absorption of iron (see p. 240).

The body excretes about 12 g. of sodium chloride (common salt) per day along with the urine, sweat, and faeces. About 2 g. of this is usually replaced from animal foodstuffs in the diet, so another 10 g. of common salt should be added to the food, especially when vegetable food forms a large proportion of the diet.

Although man's iodine requirement is very small (only about 0·005 g. per year), this element is essential for the proper development of body and brain. Iodine is present in sea-water, and small quantities are carried inland by winds bearing evaporated sea-spray. Plants absorb these iodine compounds from the soil, so that there is seldom any lack of iodine in the food except in regions very far from the sea, where it is sometimes necessary to add a little *sodium iodide* to the common salt used with food. Sea-salt and sea-water fish are good sources of iodine.

Lack of iodine causes one form of *goitre*, a disease of the *thyroid gland*, which lies in the front of the neck (see Fig. 48) and contains about a quarter of all the iodine in the body. In the commonest type of goitre, the thyroid gland becomes much enlarged, and any such swelling should be examined by a doctor, since although iodized table-salt usually *prevents* goitre, it will not always *cure* the disease. Since too much iodine in the diet may be dangerous to the health, any artificial addition of iodine should be under medical control. In some districts where goitre was formerly common, a suitable proportion of sodium iodide is added to all table-salt before distribution to shop-keepers for sale to the public.

VITAMINS

Many experiments have been done (mostly with rats, but some with men), which have actually proved that carbohydrates, fats, proteins, water, and certain mineral salts are necessary to an animal if it is to grow or remain healthy. In 1910, while carrying out some of these experiments, in England, Professor Gowland Hopkins fed rats on a theoretically correct diet of *pure* carbohydrate, *pure* fat, *pure* protein, salts and water, which at that time were believed to be the five essential kinds of food. The rats became thinner and thinner and finally died, although they had 'plenty of food'. From this experiment, Hopkins concluded that there must be other '*accessory food substances*' which must be present in an animal's food, though only in very small quantities. When he fed other rats on the same diet *with the addition of a small quantity of fresh milk or fresh fruit juice*, he found that the rats kept quite healthy, hence there must be something in fresh milk and fresh fruit which is essential for life, although only exceedingly small amounts are required to maintain health (see Fig. 25). It is now known that there are at least a dozen of these 'accessory food substances' which we call *vitamins*.

In the days of long voyages by sailing-ship, sailors often suffered from a painful and dangerous disease called *scurvy* when their voyages from port to port lasted for more than a few weeks. For example, Vasco da Gama, during his famous voyage round the Cape of Good Hope in 1498, lost over 100 seamen, all of whom died from scurvy. Captain Cook, in 1772, made his long voyage to Australia without any of his crew suffering from scurvy, and we now know that the fruit and vegetables which he included in their rations supplied a vitamin which prevents scurvy. About

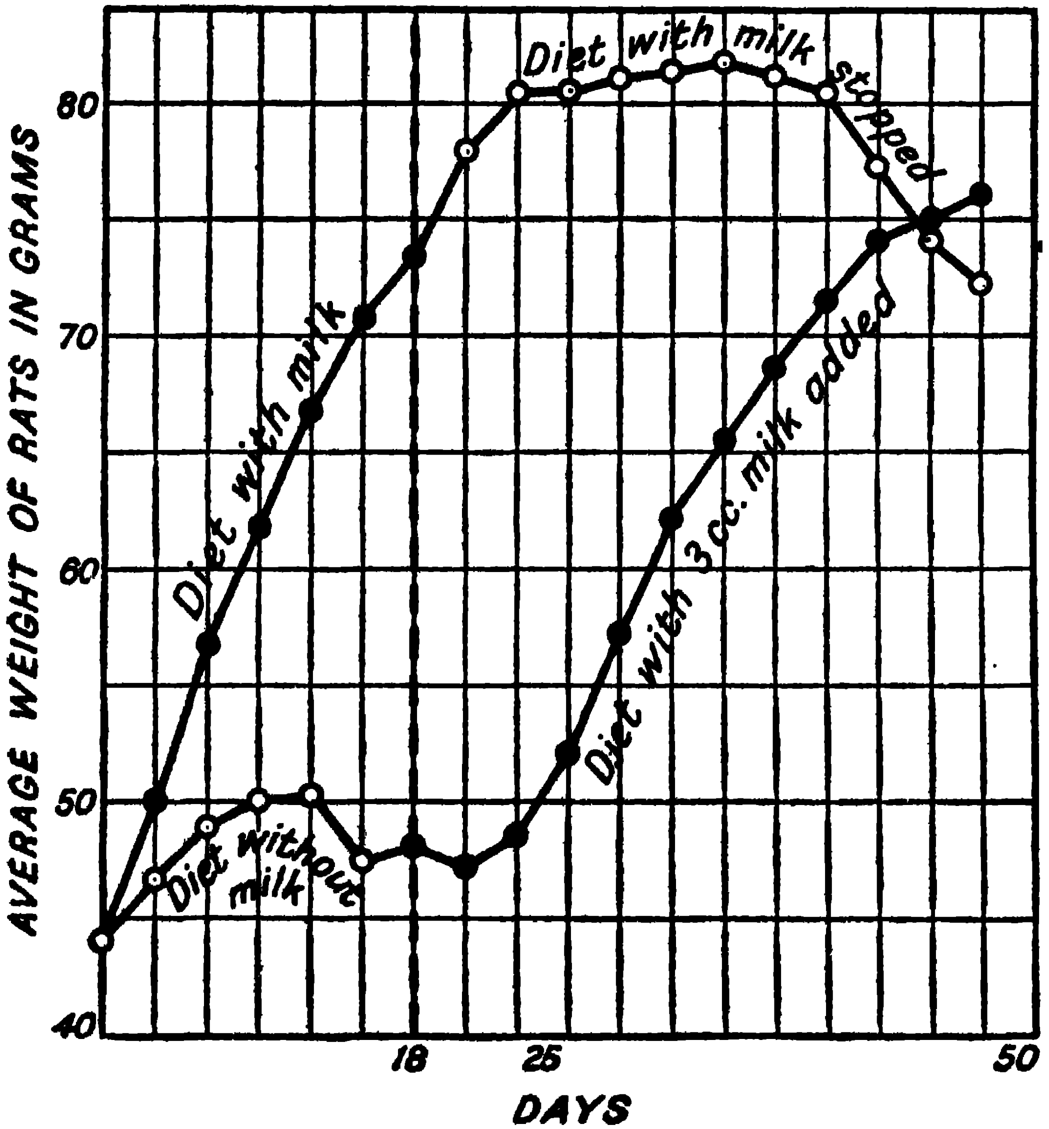


FIG. 25.—Results of one of Hopkins's historic experiments

the same time, Lind found that oranges and lemons cured scurvy (besides preventing it) and, in time, British ship-owners were compelled by law to supply lemon-juice to their sailors during long voyages.

Another *deficiency-disease* caused by lack of a vitamin is *beri-beri*. This disease attacked about one-third of the sailors in the Japanese Navy up to 1884, when the standard naval ration of meat and *white* rice was changed by substituting *whole-grain* barley for part of the white rice. The Japanese

Army ration of meat and white rice, however, was left unchanged. During the Russo-Japanese War, 200,000 Japanese *soldiers* suffered from beri-beri, *but no sailors.* So there seemed to be something in *whole-grain* barley which prevented the disease. At about the same time, in Java, the change-over from hand-mills to machine-mills producing whiter rice had been followed by more beri-beri. In 1897, Dr. Eijkmann, a prison-doctor, noticed that beri-beri attacked not only the prisoners but also the domestic hens which fed on waste food from the prison-kitchen. So he carried out experiments on the hens, feeding some of them on *whole-grain* rice, some on *half-milled* rice, and others on *white, polished* rice. *Beri-beri developed only among the birds fed on white rice* and was cured by giving them half-milled or whole-grain rice. Dr. Eijkmann then repeated his experiments on large numbers of human prisoners and found that 39 per cent. of those eating only white rice developed beri-beri, while only 1 in 10,000 of the prisoners eating half-milled rice got the disease. This experiment showed clearly that *there is something in the outer layers of the rice-grain that prevents beri-beri.* This substance was later called Vitamin B.

The first *accessory food substances* to be identified were vitamin A (formerly called the anti-infective vitamin), vitamin B (the anti-beri-beri vitamin), and vitamin C (the anti-scurvy vitamin). The original vitamin A was later found to consist of at least three substances which were then named vitamin A, vitamin D (preventing *rickets*), and vitamin E (controlling reproduction). Hence a foodstuff that contains vitamin A usually contains vitamins D and E as well. The original vitamin B was afterwards found to contain at least two substances, one destroyed by boiling (vitamin B_1—preventing beri-beri) and the other not destroyed by boiling (vitamin B_2—or vitamin G in America) which prevents a skin-disease in rats. This vitamin B_2 was later found to contain another substance—*nicotinic acid*—called the P-P vitamin because it prevents *pellagra*, a wasting disease common among people who live mainly on maize, with little or no milk or meat (see also p. 65). Vitamin K is essential for normal clotting of blood, and if it is deficient in the diet bleeding from cuts and wounds is difficult to check. Vitamin K is present in green vegetables and fresh fruits.

Vitamins A, D, E, and K are *fat-soluble vitamins*, i.e. they will dissolve in oils and fats but not in water. Vitamin C and the vitamins of the B group are *water-soluble vitamins*; they will dissolve in water but not in oils or fats. You will appreciate the practical significance of this distinction later in connexion with the cooking of food.

Before considering in detail the functions and sources of the most important vitamins you should realize that there is no magic or mystery about them. The vitamins are simply substances needed by the body (in very small amounts) and which the body cannot itself supply. *If the diet is planned with reasonable care and intelligence, our daily food supplies enough of all the necessary vitamins*, and there should be no need to buy 'vitamin pills' from the drug-store (although these concentrated vitamin preparations are very useful to doctors who fully understand their action and who have been trained to recognize the symptoms of vitamin deficiency). Remember that many of our ancestors lived very long and quite healthy lives with no vitamins other than those derived from their daily food. If you eat fresh, natural food—plenty of green vegetables, fresh fruit, milk, and eggs—you will get all the vitamins you need. Modern science has merely studied their action, isolated them in a state of purity, analysed them chemically, and measured and standardized their effects, and some of them have even been *synthesized* in laboratories, i.e. built up from simpler constituents instead of being extracted from natural foodstuffs.

Vitamin A—its sources and effects

Vitamin A encourages healthy growth and physical fitness and, unlike vitamins B, C, and D, a shortage of vitamin A in the diet does not cause any special deficiency disease. Young animals, however, soon stop growing and then die if vitamin A is not present in their food. This vitamin keeps healthy the moist surfaces lining the food-canal, the lungs and air-passages, the ducts of the various glands, and the covering-tissue that lines the eye-lids and covers the front of the eye-ball. As vitamin A helps these tissues to build up resistance to infection, it was formerly called the *anti-infective vitamin.* Some of the commonest disorders among people in tropical countries are caused by a shortage of vitamin A, when these moist covering-tissues become dry and rough. This often causes a serious eye-disease, followed by infection of the air-passages. The skin may also become dry and rough. Another defect caused by shortage of vitamin A is '*night-blindness*', when the person affected can see distinctly only in bright light. All these ill-effects of vitamin A deficiency are commoner in tropical countries than elsewhere.

The actual substance vitamin A is found only in yellow animal fats (e.g. liver-fat and butter), in egg-yolk, milk, and cheese. It is particularly plentiful in fish-liver oils (e.g. of halibut, cod, and shark), hence fish-liver oils are used for preventing and curing diseases caused by lack of vitamin A (and they also supply vitamin D).

Although vitamin A itself is not present in plants, many plants produce a substance—*carotene*, formed from leaf-green—which our bodies can convert into vitamin A. Carotene is the yellowish-red colouring-matter in *carrots*; hence the name. Since both leaf-green and carotene are formed in sunlight, the deeper green a leaf is, the more carotene it usually contains. Hence the importance of *green, leafy vegetables* in the diet, as a source of carotene, which the body can convert into vitamin A. *Root*-vegetables (except when red or yellow in colour like carrots and red-skinned sweet-potatoes) contain little or no carotene. Tomatoes, papayas, mangoes, and bananas contain more carotene than most other fruits. *Red*[1] *palm-oil* contains so much carotene that it can be used instead of cod-liver oil. It is therefore very valuable, both as a food-fat and for deep frying.

Vitamin A and carotene are insoluble in water and they are not destroyed by heat unless oxygen is present. Boiling in water, therefore, does not result in much loss of either vitamin A or carotene. Shallow frying or roasting in presence of air, however, will destroy some of the vitamin A in animal fats. Tinned meat and milk keep their vitamin A, as they are prepared and preserved in closed vessels, in the absence of air.

The vitamin A values of some common tropical foods are given on p. 237.

Vitamin B_1

Vitamin B_1 (or *thiamine*) is the *anti-beri-beri vitamin*, and if it is absent from the diet the digestive system is first disturbed, then the nerves, muscles, and heart become affected. Unless sufficient vitamin B_1 is supplied in time, the sufferer from beri-beri dies. The full disease is produced only by a serious shortage of vitamin B_1. If the diet contains some vitamin B_1, but not enough, then the nervous system, the digestive system, and the blood circulation are affected, but without producing clear signs of any special disease.

Beri-beri is commonest in countries where rice is the main foodstuff, because most of the vitamin B_1 is in the outer layers of the rice-grain and is removed when the grain is highly milled to produce *white* rice. Hence people that live mainly on white, polished rice without eating other foodstuffs rich in vitamin B_1 often suffer from beri-beri. For the same reason, a diet that consists mainly of *white* wheat-flour or cassava-flour (tapioca) may also cause beri-beri. The amount of vitamin B_1 required seems to depend partly on the amount of carbohydrate and fat eaten; the more carbohydrate, the greater the need of vitamin B_1, while fat has what is called a 'vitamin B_1 sparing' action. If the diet consists mainly of foodstuffs containing vitamin B_1, the correct balance is maintained, but if the diet consists mainly of white, polished rice, lacking in vitamin B_1, then the more rice that is eaten the sooner the deficiency is felt. Hence beri-beri attacks the 'over-fed' (who eat more white rice) before the 'under-fed' (who eat less white rice) if their other foodstuffs are the same.

---

[1] i.e. palm-oil from which the red colour has not been removed.

A *little* vitamin B_1 is present in nearly all natural foodstuffs, but relatively rich sources are egg-yolk, liver and kidney, dried peas and beans, pulses, ground-nuts (pea-nuts), and *whole grains* (e.g. rice, wheat, maize, millet, and barley). The richest source of vitamin B_1, however, is *yeast*, which is often used to correct vitamin B_1 deficiency and to prevent and cure beri-beri. *Food-yeast* is now prepared in large quantities in some tropical countries, the yeast (a microscopic one-celled plant) being grown on molasses, a by-product from the cane-sugar industry. Besides being an excellent source of vitamins of the B group, nearly half its dry weight consists of protein of good biological value. Yeast protein greatly improves the value of the protein present in cereals when eaten with them. In fact, experiments with animals have shown that when food-yeast is added to a cereal diet the value of the mixture is almost as great as that of a mixture of cereals and milk. Half an ounce of food-yeast per day is a very valuable addition to any diet.

Since *rice* is the main foodstuff of nearly half the world's population, it is important that its food-value should not be spoilt by bad methods of milling, storing, handling, and cooking. A comparison of the chemical analysis of 'brown' (husked) rice with that of white (polished) rice shows that very serious losses take place during milling. About 30 per cent. of the protein is removed, 80 per cent. of the fat, 85 per cent. of the calcium compounds and 65 per cent. of the iron compounds. Beri-beri does not develop when whole, 'brown' rice or lightly-milled rice is eaten, since most of the vitamin B_1 is in the outer layers of the grain. Hand-pounded brown rice retains a large proportion of the outer layers and is therefore richer in thiamine than machine-milled white rice. A pound of *brown* rice per day supplies enough vitamin B_1 to protect a man from beri-beri, although this represents a bare minimum of the vitamin. Most uneducated people, however, prefer white rice, from which all the outer layers and nearly all the vitamin B_1 have been removed by over-milling. They think white rice is 'cleaner', while shop-keepers find white rice more profitable to sell because it keeps longer than under-milled rice. Education is needed to change peoples' food-habits.

In some countries *parboiled rice* is eaten in place of white rice, and in such areas beri-beri is very rare. Rice in the husk is first soaked in water and then steamed and dried before milling. During the soaking and steaming, some of the soluble vitamin B_1 diffuses into the middle of the grain so that it is not removed by milling. Parboiling also toughens the grain so that less damage is done when it is milled. Most grains of polished rice show a small hollow at one end (see Fig. 26) marking the spot previously occupied by the seed-plant (or embryo). Grains of parboiled rice, on the other hand, do not show this hollow because very little of the embryo has been rubbed off. Although the embryo forms only about 1·5 per cent. of the whole grain, it contains about 60 per cent. of the total thiamine. This is lost when rice is highly milled but retained when rice is milled after parboiling. The modern process of 'Rice-Conversion' is only a refinement of parboiling, but instead of being steamed at atmospheric pressure, and then dried in the sun, the grain is first subjected to a greatly *reduced* pressure in 'vacuum' vessels before being soaked under greatly *increased* pressure. The 'converted rice' is then dried in 'vacuum' vessels before being milled as usual. The finished product retains about 90 per cent. of the thiamine present in the original grain. Parboiled and 'converted' rice, therefore, contain much more thiamine than ordinary white rice, and consumers of these kinds of rice rarely suffer from beri-beri.

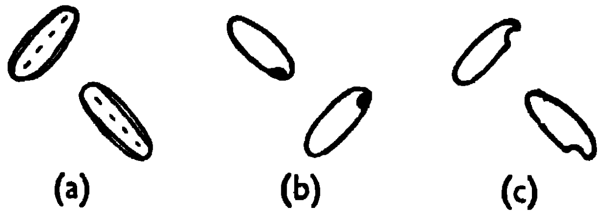


FIG. 26.—Stages in milling rice
a) whole rice, (*b*) husked rice, (*c*) polished rice

Since over-milling of 'raw' rice removes most of the thiamine, fat, calcium, and iron, the 'rice-meal' removed during milling is a very valuable foodstuff; in fact, an extract of this material can be used for curing beri-beri. (In some countries this by-product from rice-mills is fed to pigs, so it is not surprising to find that pork is the only kind of meat containing much vitamin B_1.)

Where highly-milled white rice is the main foodstuff, the following special precautions are necessary to prevent beri-beri: (i) *The rice must be properly stored,* before and after milling, to prevent loss of its thiamine, i.e. the rice must first be thoroughly dried and then kept out of contact with the air. (ii) *The rice must not be washed before cooking.* Since thiamine is soluble in water, washing the rice before cooking removes most of this vitamin. When *polished* rice is used, washing is necessary to remove the powder used to polish the rice; hence the use of polishing-powders by rice-millers is undesirable from the consumer's point of view. If the rice has been properly stored and if it is freshly milled (without using a polishing-powder) then there is no need to wash it. (iii) *No excess of water must be used in cooking the rice.* If too much water is used, much of the thiamine and mineral salts will be extracted by the excess water. If the rice absorbs *all* the cooking-water, then there are no losses. (If the rice does not absorb all the cooking water, this must not be thrown away—it is particularly valuable for diluting tinned milk or for mixing with dried milk.) (iv) *More thiamine must be supplied by foodstuffs other than rice,* e.g. food-yeast, pulses, soya-beans, ground-nuts, peas, or beans.

Vitamin B_1 is not destroyed by heat during cooking except in the presence of alkalis. Some people add a little baking-soda to the water in which green vegetables are cooked, in order to preserve their green colour. This is a very bad practice since it destroys any vitamin B (and also vitamin C). The vitamin B_1 values of some common tropical foodstuffs are given on p. 238.

Nicotinic acid—the pellagra-preventing vitamin

Pellagra is a disease that is commonest among people living mainly on maize and maize-products. The skin becomes rough and scaly and very painful, particularly when the affected places are exposed to sunlight. The digestive and nervous systems are also affected and, if proper treatment is not given, the patient gradually wastes away. The disease is common in the southern part of the U.S.A., but it also exists in a number of tropical countries among people living mainly on grain products with little animal foodstuff. People that eat enough meat, eggs, fish, milk, cheese, and green leafy vegetables do not suffer from pellagra, because these protective foods contain *nicotinic acid* (or *niacin*), another vitamin of the B group, which is sometimes called the pellagra-preventing vitamin (or the P-P vitamin). Pellagra, however, probably always results from shortage of more than one vitamin besides nicotinic acid.

Yeast is very rich in nicotinic acid and is used to cure pellagra.

Riboflavin—vitamin B_2

Another vitamin of the B group is *riboflavin* (or vitamin B_2). A lack of riboflavin in the diet does not cause any definite 'deficiency disease', but it is essential for healthy growth and, along with thiamine and nicotinic acid, for proper utilization of carbohydrate by the body. It also helps to maintain the skin in healthy condition, particularly around the eyes and mouth. Riboflavin is most abundant in meat (especially liver and kidney), milk, eggs, soya-beans, green leafy vegetables, and yeast.

Vitamin C—ascorbic acid

Vitamin C is the *anti-scurvy vitamin.* It has been identified as *ascorbic acid* since this substance, synthesized in the chemical laboratory, has exactly the same properties as the vitamin C that is present in fruits and vegetables. If vitamin C is absent from the diet for many weeks through lack of fresh fruit or vegetables, *scurvy* develops. Scurvy is a very serious disease which finally affects almost every part of the body but particularly the blood-system, where the walls of the capillaries become so weakened that blood readily escapes into the tissues. The lightest blow causes a bad bruise. Painful swellings form round the joints and in the limbs. The gums swell up round the teeth, which become loose. Scurvy always causes death unless vitamin C is supplied in time. Almost miraculous cures are brought about in a few days by comparatively small quantities of orange-juice or lemon-juice, and, after 1795, scurvy was prevented in the British Navy by giving every sailor 1 ounce (= about 30 c.c.) of lemon-juice every day. A man's minimum daily requirement of vitamin C to prevent scurvy is 0·01 g. of ascorbic acid, but two or three times as much should be taken to ensure good general health, since a shortage of vitamin C causes other troubles besides scurvy. Shortage of vitamin C is very common in the diets of tropical races. In some cases, the deficiency is enough to cause scurvy, but in most cases, although the diet contains sufficient vitamin C to prevent the full disease, there is not enough of it to prevent other troubles, e.g. shortage of vitamin C in the diet lowers a man's resistance to bacterial infection, so that wounds form a lot of *pus* and heal very slowly. In the same way, a diet containing just enough vitamin C to prevent scurvy will not provide for proper bone and tooth formation, so that the teeth become loose and readily decay. The gums also become soft and bleed easily; in fact, this is one of the first signs of vitamin C deficiency.

Vitamin C is present in *fresh* fruits and green leafy vegetables, e.g. orange, lemon, pumelo, lime, guava, papaya, mango, pineapple, tomato, spinach, lettuce, French beans, cabbage, sweet potato. Papaya is particularly rich in vitamin C (and also in carotene, which can supply vitamin A).

Although many green leafy vegetables contain more vitamin C than fruits, *fresh fruit* is the most important source of vitamin C in practice because it is usually eaten raw and uncooked. Ascorbic acid is readily oxidized and is quickly destroyed by cooking, drying, or exposure to sunlight. Since vegetables are usually cooked before being eaten, much of their vitamin C is lost. *All* their vitamin C is destroyed if soda is added during cooking. The addition of acid, e.g. vinegar, lime-juice, or tamarind, however, preserves their vitamin C. Green vegetables should always be *cooked quickly*, using the smallest convenient quantity of boiling water, for about 10–15 minutes, if they are to retain as much of their vitamin C (and their carotene) as possible. (*Slow* cooking, even at a low temperature, destroys most of the vitamin C in vegetables.) Green leafy vegetables also lose much of their vitamin C (and of their carotene) if they are not eaten in *fresh* condition. Vegetables grown in the home garden and cooked in a young, fresh condition, therefore, are better sources of vitamin C (and of carotene) than wilted vegetables which have been picked a long time before they are used. Fruits and vegetables preserved in tins by modern methods retain their vitamin C since all the air is removed from their tissues before the tin is sealed. When fresh fruits and vegetables are unobtainable, the canned material is a good source of vitamin C.

Another valuable source of vitamin C when fresh fruits and vegetables are unobtainable is *germinating grains and pulses*. Although dried seeds contain little or no vitamin C, they produce comparatively large quantities of ascorbic acid when they germinate. If grains and pulses, e.g. millet, maize, barley, peas and beans (including soya-beans), after soaking in water, are allowed to germinate, these germinated seeds, eaten raw or after boiling for a short time, form a valuable foodstuff supplying vitamin C.

Animal flesh-foods, milk, and cheese, contain little vitamin C. Remember that, for practical purposes, the best source of vitamin C is *fresh fruit, eaten raw* (after proper washing, of course, in the case of fruits not protected by a thick unbroken skin). The vitamin C values of some common tropical foodstuffs are given on p. 239.

Vitamin D—calciferol

Vitamin D is the *anti-rickets vitamin*. If there is a serious shortage of vitamin D in the body, then rickets develops. Rickets is mostly a disease of childhood in which the bones and teeth do not harden properly, although adults may suffer from similar bone diseases if they get too little vitamin D. Vitamin D acts by controlling the absorption of calcium and phosphorus compounds from the digested food as it passes through the small intestine. In the absence of vitamin D, although the food may contain plenty of calcium and phosphorus compounds, these elements are not absorbed.

Vitamin D is present in animal fats (along with vitamin A). The richest natural sources are the livers of fishes (e.g. shark, cod, halibut) and these *fish-liver oils* are used for preventing and curing rickets. Ordinary foodstuffs supplying vitamin D are fat fish, fat meat, egg-yolk, milk, and butter (if the cows have been exposed to sunlight). Most people living in tropical countries eat little animal fat and thus get little actual vitamin D *in their food.* Fortunately, however, green plants produce small quantities of a related substance called *ergosterol,* which is changed into vitamin D when it is exposed to sunlight. This change can also take place in the human skin if ergosterol is present in the fat underlying the skin. For this reason, rickets is an uncommon disease in the tropics, in spite of the small amount of animal fat usually eaten, but the disease sometimes attacks babies brought up inside dark houses and away from sunlight, especially when they are fed on sweetened condensed milk. The disease is not often seen in older children in the tropics because either the baby dies from chest, stomach, or intestinal complaints (to which rickety babies are specially liable) or else, after learning to crawl, the baby gets out into the sunlight often enough to cure the rickets. Remember, however, that exposure to sunlight alone will not prevent rickets. Ergosterol must first be present in the body, supplied by eating green leafy vegetables.

Although ergosterol is present in green plants in only small quantities, it is much more plentiful in *yeast,* and it is now extracted commercially from this source. After exposure to 'artificial sunlight' from mercury discharge lamps, this ergosterol is converted into *calciferol,* and this 'synthetic vitamin D' is added to foodstuffs that lack this vitamin, e.g. dried milk, and *margarine* (used instead of butter, and made from vegetable oils that lose their original vitamin D in the process of 'hardening' to produce solid fats). (*N.B.* Now that vitamin D can be bought so readily in concentrated form, e.g. in pills, there is a danger that ignorant people may take *far too much* and get deposits of calcium phosphate in the wrong parts of their bodies.)

PROTECTIVE FOODS

We have seen that although a man's first requirement is enough energy-yielding and body-building food, the diet must also include foods supplying vitamins and mineral salts, i.e. *protective foods*. After reading so much about the importance of vitamins, do not think that a man can live on vitamins alone; the diet must be adequate in *quantity* as well as in *quality*, and no amount of vitamins and mineral salts will keep a man healthy if his diet does not include sufficient energy-yielding and body-building food.

When the term 'protective foods' was first used, it was applied only to milk and green vegetables, but its meaning was later extended to include other foodstuffs rich in vitamins and mineral salts and also to a few other foodstuffs (obtained from animal sources) of special value for supplying the essential amino-acids. The list of protective foods published by one international authority includes green leafy vegetables, fresh fruits, whole-grain cereals and pulses, fish-liver oils, milk and milk-products, meat, fish, and eggs. These protective foodstuffs are often missing from tropical diets, one reason being that they are usually more expensive and less satisfying than carbohydrate foods. Another reason is that when the diet lacks protective foods there is not the same feeling of *hunger* as when energy-yielding foods are lacking. A shortage of protective food in the diet may not cause clear signs of illness, but people living on such badly-balanced diets exist only on the fringe of good health and never attain that physical and mental well-being which is necessary to the enjoyment of full health with a keen mind and a vigorous body.

When the diet lacks sufficient energy-yielding food, one feels hungry and tries to eat more food to satisfy the hungry feeling. Lack of protective food, on the other hand, does not cause obvious hunger but results in general tiredness and a lessened capacity for mental and physical activity. These effects of shortage of protective food are not so easily recognized as the hunger that results from lack of energy-yielding foods, hence the need for intelligent *planning* of balanced diets. Fig. 27 shows, diagrammatically, the essential constituents of a balanced diet and the common foodstuffs that will supply these essentials. The table on p. 236 shows, in quantitative form, how everyday food needs can be met.

With the knowledge gained so far, you should now be able to judge for yourself the extravagant claims made in advertisements of patent medicines and foodstuffs which are said to do wonderful things for your health and strength. Uneducated people often waste a lot of money because, not having the necessary knowledge and outlook to check such claims, they believe any statement made in print.

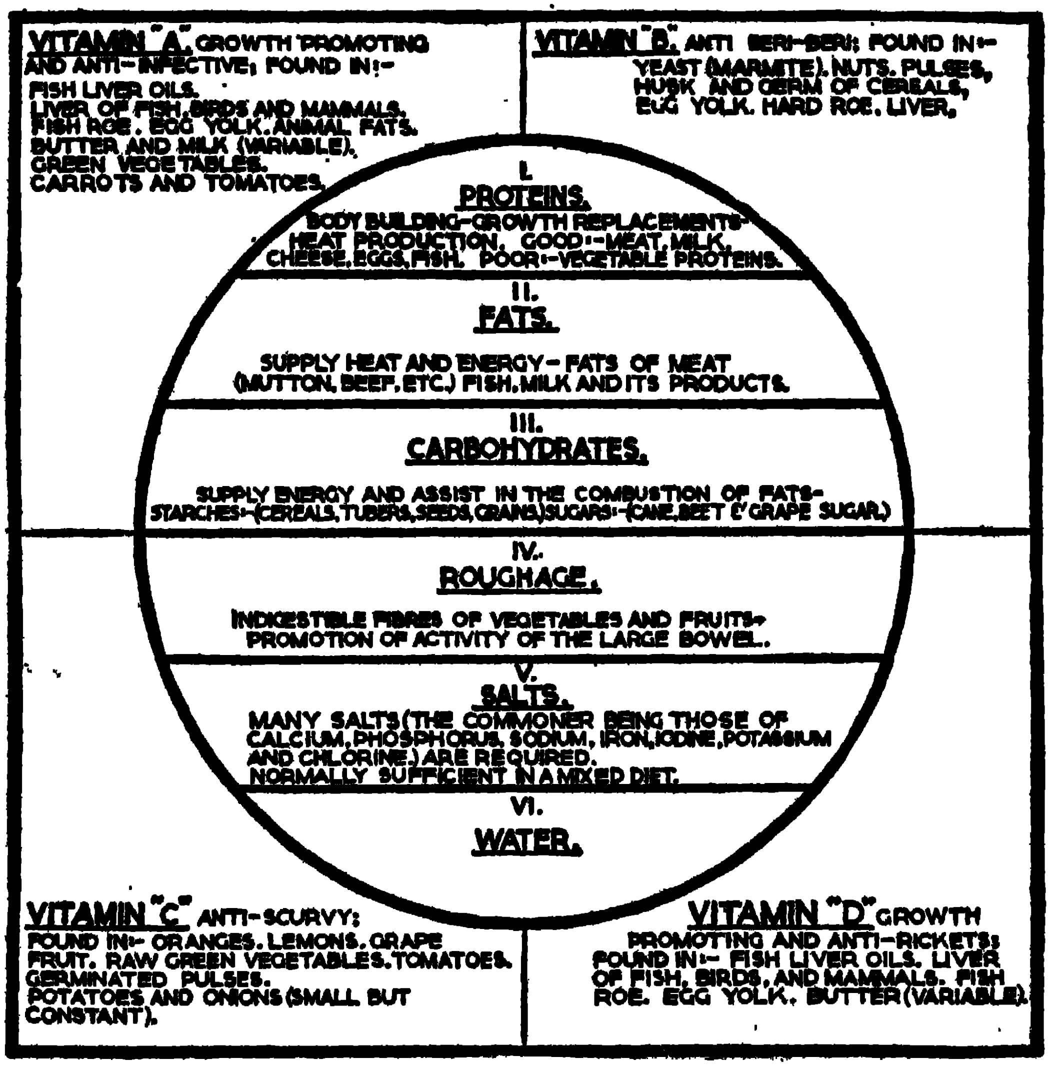

VITAMIN "A." GROWTH PROMOTING AND ANTI-INFECTIVE; FOUND IN:-
FISH LIVER OILS.
LIVER OF FISH, BIRDS AND MAMMALS.
FISH ROE. EGG YOLK. ANIMAL FATS.
BUTTER AND MILK (VARIABLE).
GREEN VEGETABLES.
CARROTS AND TOMATOES.
VITAMIN "B." ANTI BERI-BERI; FOUND IN:-
YEAST (MARMITE). NUTS. PULSES,
HUSK AND GERM OF CEREALS,
EGG YOLK. HARD ROE. LIVER.
I.
PROTEINS.
BODY BUILDING-GROWTH REPLACEMENTS-
HEAT PRODUCTION. GOOD:-MEAT, MILK,
CHEESE, EGGS, FISH. POOR:-VEGETABLE PROTEINS.
II.
FATS.
SUPPLY HEAT AND ENERGY - FATS OF MEAT
(MUTTON, BEEF, ETC.) FISH, MILK AND ITS PRODUCTS.
III.
CARBOHYDRATES.
SUPPLY ENERGY AND ASSIST IN THE COMBUSTION OF FATS-
STARCHES:-(CEREALS, TUBERS, SEEDS, GRAINS) SUGARS:-(CANE, BEET & GRAPE SUGAR.)
IV.
ROUGHAGE.
INDIGESTIBLE FIBRES OF VEGETABLES AND FRUITS-
PROMOTION OF ACTIVITY OF THE LARGE BOWEL.
V.
SALTS.
MANY SALTS (THE COMMONER BEING THOSE OF
CALCIUM, PHOSPHORUS, SODIUM, IRON, IODINE, POTASSIUM
AND CHLORINE.) ARE REQUIRED.
NORMALLY SUFFICIENT IN A MIXED DIET.
VI.
WATER.
VITAMIN "C" ANTI-SCURVY;
FOUND IN:- ORANGES. LEMONS. GRAPE
FRUIT. RAW GREEN VEGETABLES. TOMATOES.
GERMINATED PULSES.
POTATOES AND ONIONS (SMALL BUT
CONSTANT).
VITAMIN "D" GROWTH
PROMOTING AND ANTI-RICKETS;
FOUND IN:- FISH LIVER OILS. LIVER
OF FISH, BIRDS, AND MAMMALS. FISH
ROE. EGG YOLK. BUTTER (VARIABLE).

FIG. 27.—'A square meal'

SOME IMPORTANT FOODSTUFFS

Milk

The only single foodstuff that contains all the essentials of a good diet is milk. It contains a soluble carbohydrate (milk-sugar, or lactose), a substance found in no other natural food. The proteins of milk (e.g. casein) have the highest food-value of all proteins because they supply the amino-acids most needed for growth in the young and for repair in the adult. Milk-proteins, eaten together with cereals, improve the nutritive value of the 'poor' cereal-proteins. Milk-fat is present in the form of an emulsion of different fats of low melting-point, providing the most easily digested kind of fat known to science. Milk is also particularly rich in mineral salts, especially in the calcium salts and phosphates necessary for building bone. Milk contains nearly all the essential vitamins, but the maximum amount of these is only found in the milk of dairy animals fed on fresh, green herbage and exposed to sunlight. Vitamin C, however, is present in very small quantity, and as this vitamin may be destroyed by heating it is necessary to get it from another source, e.g. fresh fruit.

Milk forms a complete food for the young of mammals during their early life, and every different mammal produces a different kind of milk (containing different proportions of the above constituents—see Fig. 28) which forms a perfectly balanced food for its own young. After the earliest stages, however, solid food is necessary in addition to liquid milk.

Unfortunately, little or no milk is included in most tropical diets, and there are only a few tropical countries where milk-production from cows, buffaloes, sheep, goats, or camels is a profitable business. Unfortunately, also, milk may be either the most valuable or the most dangerous of foods, since it is so easily contaminated with disease organisms between the time it leaves the dairy animal and the time it is used for food (even when the animal that supplies the milk is perfectly healthy—which is not always the case). Badly neglected milk may contain more bacteria than sewage, and may carry tuberculosis, typhoid fever, and diphtheria. In fact, a town's milk supply often needs more careful watching than its water supply. Hence the importance of making sure that the daily household supply comes from *healthy animals*, *cleanly milked* by healthy people, and that it is supplied in *clean*, *covered containers*.

The 'purity' of milk depends very largely on the precautions taken during milking, for it is while the animal is being milked that contamination most easily takes place. The following precautions are necessary: (*a*) the hind-quarters, udder, and teats must first be cleansed, (*b*) the milker must have clean, dry hands before beginning to milk and must keep them clean and dry while milking, (*c*) the vessels in which the milk is collected must be clean, and (*d*) milking must be done in a good light.

Milk, as it comes from the udder, is at the most favourable temperature for the growth and multiplication of bacteria. In modern dairies, therefore, the milk is usually cooled down as soon as possible (to not more than 50° F.) so as to check the multiplication of germs (without, however, killing those already present). To kill harmful germs (particularly those of tuberculosis) milk may be *pasteurized* by heating it to not less than

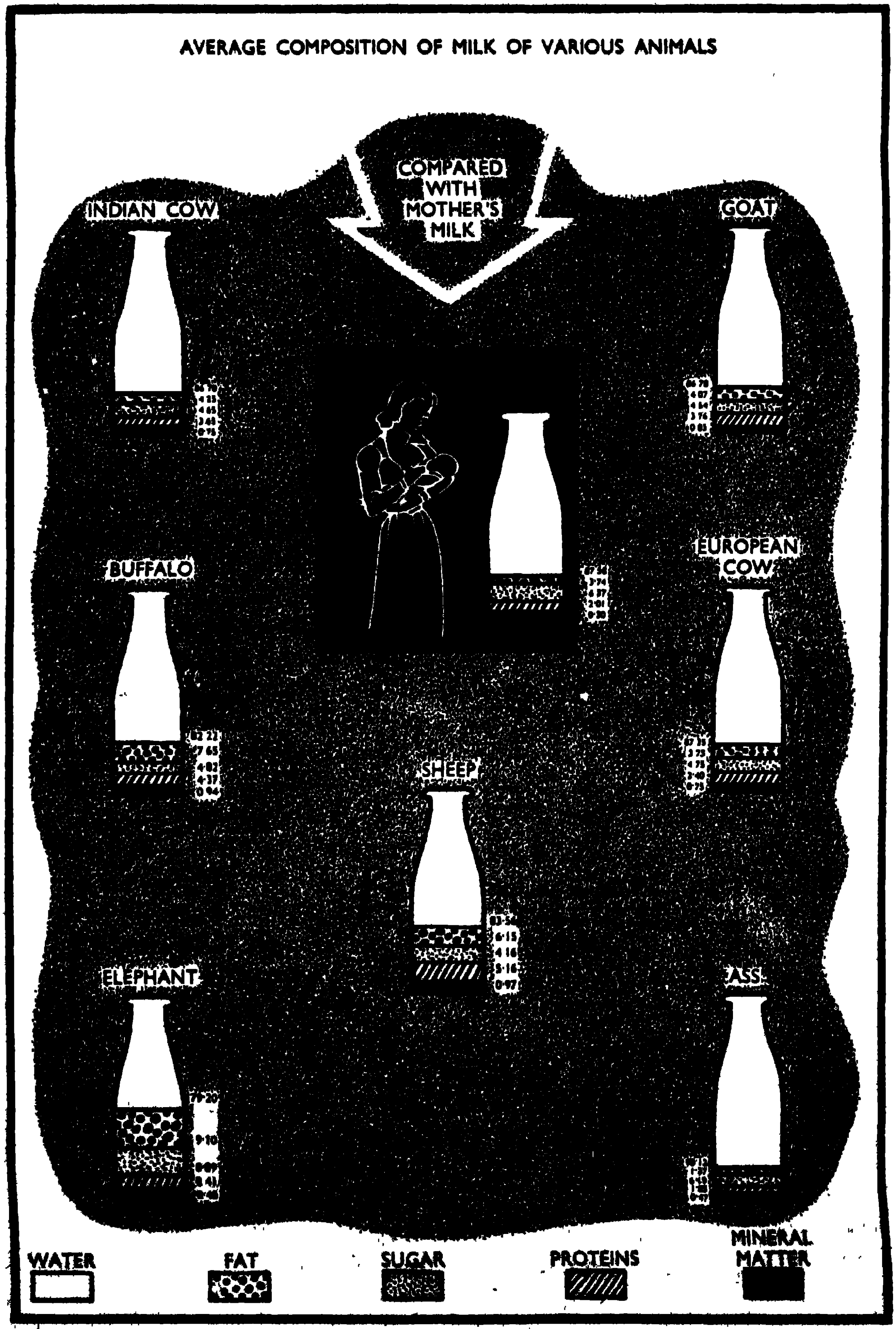


FIG. 28.—Comparative milk values

142° F. and keeping it at this temperature for not less than 30 minutes. The pasteurized milk is then *cooled very quickly* to not more than 50° F. If milk is *boiled* (at 212° F.), harmful germs are killed, but the food-value of the boiled milk is lower than that of pasteurized milk.

In many tropical countries it is so difficult to get a daily supply of fresh, clean milk from healthy dairy cattle that imported, *preserved milk* has to take the place of fresh milk as a protective food. Milk is preserved commercially in two main ways: (*a*) as *evaporated* or *condensed milk*, containing all the constituents of fresh milk, and (*b*) as *dried milk*. *Evaporated milk* is simply milk from which about half the water has been removed by evaporation. Diluted with the proper amount of water, evaporated milk forms a good substitute for fresh milk and can even be used as an artificial food for babies. It does not keep long, however, once the can is opened. *Condensed milk* is milk from which most of the water has been removed and to which cane-sugar has been added; it is *not* the best form of preserved milk for feeding babies, being liable to cause boils and looseness of the bowels. *Dried whole milk* is whole milk from which all the water has been removed and this is one of the best forms of preserved milk. It is clean, it keeps well, and it is easily prepared for domestic uses. Dried whole milk is the best artificial food for babies. *Dried skim milk* (or dried *separated* milk) is made from 'skimmed' or 'separated' milk, i.e. milk from which the fat (or cream) has been removed by skimming or mechanical separation. Hence it lacks fat and fat-soluble vitamins (A and D). Dried skim milk is the cheapest form of preserved milk and as it is such a rich source of proteins, calcium and phosphorus compounds, and vitamin B, it provides a valuable addition to most tropical diets, e.g. it supplies almost everything that is missing from the usual rice-eater's diet. Dried skim milk, is sometimes mixed with one volume of buffalo milk (of very high fat content) and one volume of water, thus doubling the existing milk supply in some areas. (*N.B.* Babies should never be fed entirely on dried *skim* milk, because vitamins A and D were removed along with the milk-fat when the milk was skimmed; the addition of egg-yolk, however, will replace the missing vitamins and fat.)

Cheese, which contains milk-protein and milk-fat, has many of the valuable food properties of milk and makes a good substitute for meat.

Eggs

Eggs are a very valuable foodstuff, being particularly rich in protein (mainly in the egg-white) and fat (mainly in the yolk), besides containing mineral salts and vitamins (A, B, D, and E—but *not* C). Hence eggs, eaten with carbohydrate foodstuffs, can supply a complete, properly balanced meal. Eggs make an excellent substitute for meat.

Egg-white contains four first-class proteins which supply all the essential amino-acids. Egg-yolk contains valuable quantities of vitamin B (in addition to vitamins A and D); it is about 30 per cent. fat and it also contains two first-class proteins, in addition to numerous mineral salts (including large quantities of *iron* in a form which is easily absorbed). Eggs and milk make a very good food-combination, since the deficiency of vitamin D and iron in milk can be made up from eggs. Eggs, on the other hand, lack calcium salts, which are plentiful in milk.

By keeping a few hens, fed mainly on waste foodstuffs, many families could provide themselves with a very valuable addition to their diet.

Fish

In many tropical countries, fish is the only animal protein which can be had at reasonable cost. Unfortunately, little has yet been done to make full use of the enormous wealth of protein food available in tropical seas, but several countries are now beginning to improve their methods of catching and marketing fish.

Fish is a very valuable foodstuff, supplying first-class protein to the diet. We have seen that fish-livers and 'fat' fishes are also very rich in vitamin A; sea-fish also supply iodine. Hence fish is a very suitable addition to diets consisting mainly of rice or other grains. The food-value of fish is greatest when it is *fresh*. Unfortunately, however, fish-flesh decomposes rapidly, particularly at high temperatures, and in many tropical areas dried fish is all that can be had. Cold storage is the best method of preserving fish, but it is an expensive method, used mainly in large towns. The commonest method of preserving fish is by drying, either in the sun or by hot smoke, but this usually destroys vitamins A and D. Another method is by using common salt, either by salting and drying, or by 'pickling' the fish in strong salt solution or brine.

Legumes

The seeds of many leguminous (pod-bearing) plants are valuable foodstuffs, because they supply vegetable proteins that are of high food-value when eaten with animal proteins or when added to a diet consisting mainly of rice or other grains. When eaten together, peas and rice, grams and rice, peas and maize, are of greater food-value than when eaten separately. Maize, millet, and soya-bean is one of the best combinations of this kind.

The *soya-bean* is a very important leguminous foodstuff since it contains a high proportion of good protein and fat; it is also rich in calcium compounds. We have seen (p. 67) that germinated soya-beans are rich in vitamin C. When cooked whole, soya-beans are difficult to digest, hence they are usually 'processed' to produce more readily digestible products, e.g. soya-bean flour, soya-bean 'milk', and soya-bean 'curd'. Soya-bean 'milk' is readily digestible and has a high food-value corresponding to about 80 per cent. of that of good cows' milk. The paste left after separating the 'milk' can be used for other food preparations. With the addition of calcium sulphate, common salt, egg-yolk, and invert sugar (see p. 47), soya-bean milk forms a good substitute for animal milk and can even be used as a complete food for babies.

Other legumes of high food-value are ground-nuts (rich in protein, fat, and vitamin B_1), lentils, cow-peas, pigeon-peas, lima-beans, dolichos-beans, French beans, long beans, and grams.

Green leafy vegetables and fruits

Fresh fruits and green leafy vegetables are needed to supply 'protective' vitamins and mineral salts. Fresh green vegetables, eaten raw (e.g. in the form of salads), are a good source of vitamin C (ascorbic acid). In many tropical countries, however, great caution is necessary before raw, uncooked vegetables are eaten owing to the danger of intestinal disease. Leafy vegetables bought in the market or from a hawker have sometimes been grown under insanitary conditions (e.g. in soil manured with raw human excreta) and they are often allowed to lie on dirty surfaces and to be handled by dirty hands. Vegetables from such sources are safer after cooking; it is dangerous to eat them raw. The safest source of supply for your green salad vegetables is *your own garden*; failing this, get them from a known safe source, e.g. a Government or municipal market garden, where they are grown under proper conditions, strictly supervised. In any case, vegetables that are to be eaten raw should be well washed in clean water before they are eaten.

If you cannot be sure of the cleanliness of your local supply of green vegetables, it is safer to get your vitamin C from fresh fruits (the edible part of which is less liable to contamination since it is usually protected by a skin). Fruits with damaged or broken skins should be regarded with strong suspicion. Fruits of good 'protective' value are the citrus fruits (e.g. oranges, lemons, limes, pumeloes, grape-fruit), tomatoes, papayas, pineapples, guavas, mangoes, and chillies.

When green leafy vegetables are being cooked, remember that vitamin C is easily destroyed by bad cooking. Also remember that the cooking-water contains valuable mineral salts and vitamins; it should therefore be used and not thrown away. The following rules should be observed: (i) Use green leafy vegetables *as fresh as possible*; if you grow your own (the best way) do not gather them until just before you are ready to cook them. (ii) *Wash* vegetables thoroughly (but do not *soak* them for a long time) before cooking. (iii) Use *only just enough cooking-water* to prevent burning. (iv) Add about one tea-spoonful of common salt to every pound of vegetables (but do not add any soda). (v) Keep the lid on the cooking-vessel (so that the vegetables are 'steamed' rather than 'stewed'). (vi) Boil green leafy vegetables for *10–15 minutes only*. (vii) Drain off any excess liquid and use it for making soup or gravy. (viii) Eat the cooked vegetables as soon as possible. (There is a very good reason underlying every one of these eight rules; can you think of one in each case?)

Sugar

Refined white sugar supplies nothing but energy; it has no protective value and should be used only in moderation. It is better (and cheaper) to use *starch* as your main source of energy rather than eat too much sugar. In the food-canal, the conversion of insoluble starch into soluble simple sugars is relatively slow, hence after a meal of mainly starchy food absorption of sugar from the small intestine goes on slowly and steadily without overloading the liver (which, you will remember, regulates the amount of sugar entering the blood-stream). Sweet foods, however, contain soluble sugar that is digested and absorbed very quickly, so that a lot of sugar reaches the liver in a short space of time. Under normal conditions, a steady supply of sugar to the liver is better than a sudden rush. Under abnormal conditions, however, e.g. when the blood-sugar is too low owing to lack of food or over-exertion, eating sugar will soon put things right. In fact, the simplest remedy for feeling faint is sugar, e.g. sweetened coffee or sweetened fruit-juice, because this is the quickest way of increasing the amount of glucose in the blood-stream. Sugar and sweet foods, therefore, provide a useful 'pick-me-up', but starchy foods are more satisfying and more satisfactory as a general rule. Over-sweetened starchy foods, also, often cause fermentation and 'wind' in the food-canal.

Unrefined sweetening agents like molasses and brown sugar are of greater food-value than refined white sugar because their protective 'impurities' have not been removed. Molasses and brown sugar, for example, contain some mineral salts (particularly iron compounds) and they may also supply vitamins of the B group.

COOKING

Most of our food is not eaten raw, but is first cooked. Cooking makes the food more appetizing, thus indirectly helping digestion by stimulating the flow of digestive juices, e.g. we notice an increased flow of saliva when appetizing food is seen or smelt.

When meat is properly cooked, the tough bundles of muscle-fibres are split up so that cooked meat is easier to chew with the teeth and is more readily acted upon by the digestive juices in the food-canal.

When vegetables are cooked, the plant-cells are burst open so that the digestive juices in the food-canal can act on the cell-contents more readily. At the same time, the starch-grains inside the cells are also burst open so that the starch is more readily digested.

Properly cooked bread and pastry is porous and spongy; hence, when it is eaten, the digestive juices can act on the porous food much more readily than if it were in dense, solid lumps. The particles of flour are separated from one another by the expansion of air, carbon dioxide, and steam. When flour and water are mixed together by kneading with the hands, air is trapped in the sticky dough. When the dough is heated, these bubbles of air expand and make the bread porous. Some of the water in the dough, too, forms bubbles of steam, thus producing the same effect as the bubbles of air. It is usual, however, to set free carbon dioxide in the dough before or during baking by using *yeast* or *baking-powder* (a mixture of sodium bicarbonate with a weak acid). The bubbles of carbon dioxide that are formed cannot escape from the sticky dough and, during baking, they expand and force apart the particles of dough.

Another important result of cooking food is that the high temperature used kills disease organisms and parasites that may be present in the raw food. Cooking makes meat and fish more attractive and should also make them more digestible, but it has, in addition, the very important effect of killing disease organisms, e.g. bacteria and parasitic worms. Cooked meat will keep longer than uncooked meat. Fish decays very rapidly in a hot climate and should always be cooked as soon as possible. Shell-fish decompose particularly quickly and very often carry disease organisms, so they should only be bought alive, to ensure freshness, and should then be cooked very thoroughly.

Food hygiene

It is most important that food should be stored, prepared, served, and eaten in a clean and hygienic way. The kitchen should be the cleanest place in the home; it should be well lighted, so that dirt and insects are easily seen and removed. The floor should be of smoothly-finished waterproof material so that it can be swept clean and washed easily. Table-tops and other working-surfaces should be kept clean by frequent scrubbing with soap and water. A rat-proof and fly-proof store-room or store-cupboard ('meat-safe') should be available for storing food. The wash-place (or 'sink') should be well drained and easily cleaned. Those handling and preparing other peoples' food should be scrupulously clean in their persons and in their habits; dirty hands (and dirty finger-nails) are *dangerous* if they come in contact with food. Cooking vessels need very careful cleaning with soap and water (not just dry sand or ashes) to ensure that no food is left sticking on them to decay and to feed bacteria. Chipped or cracked vessels may be dangerous because of disease germs inside small openings where they cannot be washed away. Table-ware should be washed in *hot* soapy water and then rinsed in *clean* water before being placed on a draining-rack to dry. This is better than wiping with a cloth, because unless the cloth is perfectly clean it does more harm than good. A dirty 'dish-cloth' or kitchen-towel is a paradise for bacteria and contaminates everything it wipes. Remember that although things may 'look clean' you cannot see disease germs without a microscope.

Notice that the important factor is always *cleanliness*—with clean hands, clean food, clean water, and clean surroundings we can avoid most of the diseases that enter the body by way of the mouth. In practice, the best aids to cleanliness are soap and hot water.

METABOLISM

Now that we know the essentials of *good nutrition*, i.e. what the body needs to make it grow, to supply it with energy and to keep it healthy, we can go on to consider the subject of *metabolism*, i.e. what happens to this food in the body. Since this is a complicated process in Man and other mammals, we shall study it in four separate stages: (i) *ingestion*—the intake of food, (ii) *digestion*—the process of breaking-down complex food materials into simpler, soluble, and diffusible substances that can enter the body-cells, (iii) *absorption*—the intake of soluble and diffusible food-substances by the true interior of the body, i.e. by the body-cells, and (iv) *assimilation*—the building up of these food-substances into the chemical compounds which the body requires.

Ingestion

In Man, food is taken in at the mouth with the aid of the teeth and lips. If the solid food is in large lumps, smaller pieces are bitten off by the cutting-teeth (incisors) at the front of the mouth (see Fig. 53). This food is then chewed, or ground up, by the grinding-teeth (molars) at the back of the jaws. While the teeth are tearing and grinding the food, it is wetted and softened by *saliva*, and worked into a round ball by the tongue in readiness for swallowing.

By thorough chewing, the solid food is broken up into small pieces which will offer a large surface area to the action of the digestive juices in the food-canal. (*N.B.* A liquid can only react with an insoluble solid *at its surface*, and the finer the state of division of a given weight of a solid, the greater its surface area.)

Digestion

Digestion prepares the food for absorption. After ingestion, the food passes through a long tube, the food-canal (or alimentary canal), leading from the mouth to the anus, and the complex carbohydrates, fats, and proteins are broken down into simpler, soluble substances whose molecules are small enough to pass through the walls of the food-canal into the true interior of the body. Digestion is brought about by the action of various *enzymes* which are poured into the food-canal by a series of *digestive glands*. These enzymes are *organic catalysts* produced by living cells. There are many chemical changes which take place very slowly when left to themselves, but which take place rapidly when a small quantity of a suitable *catalyst* is added. Every living cell produces organic catalysts, or enzymes, which enable the cell to carry on its life processes at a suitable speed. Each digestive gland is associated with a different part of the food-canal and produces a digestive juice containing its own special enzymes that act on part of the food as it passes through the food-canal. The enzymes concerned with digestion may be classified as (i) *carbohydrate-splitting enzymes* (*amylases*), (ii) *fat-splitting enzymes* (*lipases*), and (iii) *protein-splitting enzymes* (*proteases*). All these enzymes are destroyed by boiling.

Digestion in the mouth

In Man, digestion begins in the mouth, where the food is mixed with saliva, a slightly alkaline juice produced by the salivary glands. These glands produce 2–3 pints (= 1–1½ litres) of saliva daily. Man has three pairs of salivary glands; (*a*) a pair by the angle of the jaws, just beneath the ears, (*b*) another pair between the two halves of the lower jaw, and (*c*) a third pair beneath the tongue. Saliva softens the food and helps in swallowing, but it is also the first digestive juice, containing the enzyme *ptyalin* which changes cooked starch into sugar. In practice, the food is not kept in the mouth long enough to change much starch into sugar, hence the digestion of starch only *begins* in the mouth; it is completed later on, in the stomach and the small intestine. Ptyalin acts on cooked starch, glycogen, and dextrin, converting them into the complex sugar *maltose*, and its activity is increased when common salt (sodium chloride) is present. It has no action on complex sugars (e.g. sucrose and maltose), uncooked starch, fats, or proteins. (See page 253 for experiments illustrating the action of saliva.)

Digestion in the stomach

After being chewed and mixed with saliva, the ball of food is passed down the throat and gullet to the stomach, where it remains for several hours. Here it meets the *gastric juice*, produced by many tiny glands in the lining of the stomach-wall. These glands produce 4–6 pints (= 2–3 litres) of gastric juice daily. This gastric juice is strongly acid, owing to the presence in it of about 0·2 per cent. of hydrochloric acid, hence it gradually stops the action of the alkaline saliva as the food becomes mixed with gastric juice. In practice, this takes some time, since the last food to be swallowed goes to the *middle* of the stomach and the alkaline saliva is not neutralized by the acid gastric juice until later (see Fig. 29). Hence the digestion of starch by saliva continues in the stomach (for about half an hour). The hydrochloric acid in the gastric juice also kills most bacteria and thus prevents food fermenting in the stomach.

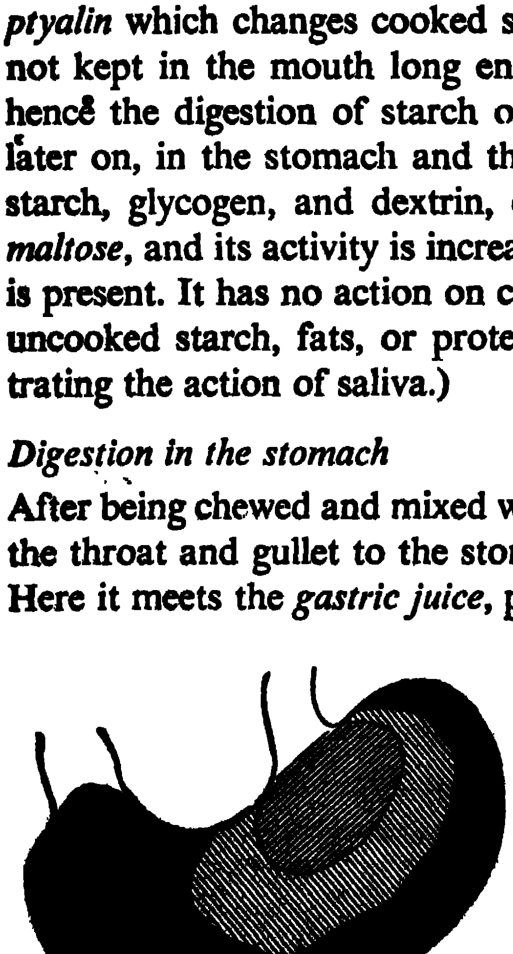


FIG. 29.—Section of frozen stomach of rat after three separate meals of differently coloured food

Gastric juice contains two enzymes, (*a*) *pepsin*, which in acid solution begins the digestion of proteins, splitting them up into simpler, more soluble substances (but without acting on the carbohydrates and fats), and (*b*) *rennin*, which clots milk so that it is retained in the stomach while pepsin acts on the milk-protein.

In the stomach, the food and the gastric juice are gradually mixed into a soft liquid mixture, and, at intervals, a ring of muscle between the stomach and the small intestine relaxes and the partly-digested food is passed, a little at a time, through an opening called the *pylorus* into the *duodenum*, the first part of the small intestine, or small bowel, where it meets more digestive juices. (See p. 253 for experiments illustrating the action of pepsin and rennin.)

Digestion in the small intestine

When the acid contents of the stomach enter the small intestine, they are neutralized by alkaline *bile* (from the liver) and alkaline *pancreatic juice* (from the pancreas). In the first part of the small intestine (the *duodenum*), starches, proteins, and fats are all split up by the action of three enzymes in the pancreatic juice which will be discussed later.

Bile is a greenish, alkaline fluid made by the liver and stored in the *gall-bladder*, 1–2 pints (= 500–1,200 c.c.) being produced daily. In Man, a small *bile-duct* introduces the bile into the duodenum. The bile contains no digestive enzymes, but, being alkaline, it neutralizes the acid of the gastric juice and thus stops the action of the pepsin. It contains *bile-salts*, which (like soap) lower the *surface tension* of water. As a result bile tends to keep the tiny droplets of melted fat and oil from running together, so that they present a much greater surface to the *lipase*, the fat-splitting enzyme of pancreatic juice. (See page 254 for experiments illustrating the action of bile.)

Pancreatic juice, like bile, is alkaline, owing to the presence of sodium carbonate. It contains three enzymes—*amylase* (starch-splitting), *trypsin* (protein-splitting), and *lipase* (fat-splitting). The starch-splitting enzyme acts on any starch that has not been split up by the ptyalin of the saliva. Amylase, however, can also act on uncooked starch, while ptyalin only acts on starch after the starch-grains have been burst by cooking. The protein-splitting enzyme—trypsin—carries the digestion of proteins a stage further than pepsin, some amino-acids being formed. The fat-splitting enzyme—lipase—splits up oils and fats into fatty acids and glycerine.

Digestion is completed by the action of the enzymes of the *intestinal* *juice*, produced by cells in the walls of the small intestine. Intestinal juice contains at least four more enzymes. One (*erepsin*) completes the digestion of proteins to amino-acids, while three others, *sucrase*, *lactase*, and *maltase*, split up the complex sugars sucrose, lactose, and maltose into simple sugars—mainly *glucose*.

A great deal of the food of plant-eating animals consists of cellulose. None of the higher animals produces a cellulose-digesting *enzyme*. Thus in Man and many carnivorous animals no use can be made of this carbohydrate, which is passed out in the faeces. In most herbivorous animals, however, the cellulose is digested in the alimentary canal by *bacteria* which live there, and some of the sugars so formed are absorbed by the animal.

It should be noted that water plays a large part in digestion. It is secreted with the enzymes and is, of course, replaced during drinking. The various enzymes dissolve in water and are thus brought to the surface of the solid food particles or of the fat droplets. Moreover, the digestive processes which we have called 'splitting' reactions are really all examples of what the chemist called *hydrolysis*—water actually entering into the chemical reactions, thus:

$$\text{STARCH} + \text{WATER} \xrightarrow{\textit{amylase}} \text{SUGAR.}$$

$$\text{PROTEINS} + \text{WATER} \xrightarrow{\textit{proteases}} \text{AMINO-ACIDS.}$$

$$\text{FATS} + \text{WATER} \xrightarrow{\textit{lipase}} \text{GLYCERINE} + \text{FATTY ACID.}$$

The products of digestion dissolve in the excess water and, after their absorption, the bulk of the water is itself taken back into the bloodstream by absorption from the large intestine.

The final products of digestion

As a result of digestion in the mouth, the stomach, and the small intestine: (i) the *proteins* are finally split up into *amino-acids*, (ii) the *carbohydrates* are finally split up into *simple sugars*, (iii) the *fats* are split up into *fatty acids* and *glycerine*, the fatty acids combining with the bile salts in the intestine to form soluble substances. All these substances are now ready for *absorption*.

Absorption

Absorption of food takes place in the small intestine. In Man, the walls of the small intestine are covered with large numbers of tiny, finger-shaped projections called *villi*, each villus being about 0·05 in. long, and containing a network of capillary blood-vessels running just beneath its thin covering layer of cells (see Fig. 30). In the centre of each villus is a blind-ended tube called a *lacteal*, which is part of the lymphatic system of the body. These villi present a very large surface-area to the digested food in the small intestine, and it is through the cells covering the villi that the digested food enters the true interior of the body. The surface area of the lining of the small intestine is further increased by transverse folds (see Fig. 30). The *simple sugars* (e.g. glucose) and the *amino-acids* pass directly into the capillary blood-vessels running through the villi. All the veins draining blood from these capillaries in the villi finally join together to form one large vein (the *portal vein*) which runs to the *liver* and then divides again into capillaries. (*N.B.* It is unusual for a vein to divide up into capillaries *at both ends*.) Some of the digested fat is absorbed into the *blood*-vessels of the villi in the form of fatty acids combined with bile salts and then passes along the portal vein to the liver. The rest is absorbed as tiny droplets of neutral fat and passes into the *lymph*-vessels of the villi, and these lacteals join together to form larger lymph-vessels, which finally

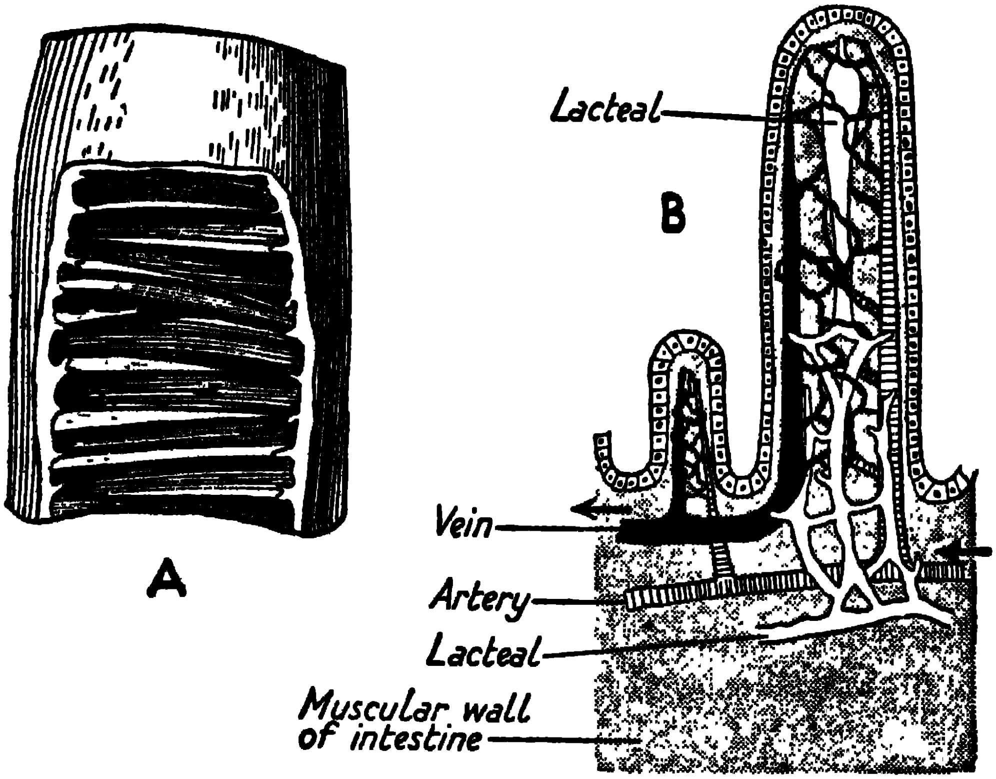


FIG. 30

A—portion of human small intestine cut open to show transverse folds
B—section through a villus, very highly magnified, showing blood-vessels and lacteals

discharge the lymph into the large vein from the left arm, at the base of the neck. The droplets of fat are then carried round the body in the blood-stream.

The excess fat is removed from the blood-stream and stored under the skin and around the organs in the body-cavity. When the animal is short of food for a long time, it makes use of this reserve fat as a source of energy.

By the time that the creamy emulsion of digested food has travelled the whole length of the small intestine, practically all the soluble constituents have been absorbed, and the indigestible residue, still mixed with much water, is passed on into the first part of the *large intestine*—the *colon*—where a lot of water is re-absorbed from the indigestible food-residues, which are reduced to about one-tenth of their former volume. The large intestine also gets rid of some waste products from the blood. This semi-solid food-waste—or faeces—collects in the looped part of the large intestine, down the left side of the body-cavity, until there is a sufficient quantity to push some of it into the *rectum*, the last portion of the food-canal. In a normal, healthy person, the presence of faeces in the rectum should at once produce a desire to evacuate the faeces through the anus.

Diffusion and dialysis

In order to understand how the final products of digestion pass through the walls of the villi, it is necessary to know more about diffusion and similar processes. If a jar of oxygen is placed mouth-to-mouth with a jar of nitrogen, the two gases soon form a uniform mixture by *diffusion*, the gas molecules moving about in all directions until the two gases are thoroughly mixed. If a test-tube is half-filled with copper sulphate solution and is then *slowly* filled up with water, *without shaking*, the blue colour gradually spreads throughout the tube until the colour is uniform. The copper sulphate molecules have *diffused* through the water in the tube. Diffusion in liquids, however, is much slower than diffusion in gases. If a solution of egg-white is used instead of copper sulphate in the last experiment, diffusion is still slower, because the protein-molecules of the egg-white are very much bigger than the copper sulphate molecules.

If a solution of sugar in water is enclosed in a membrane (e.g. parchment-paper or Cellophane) surrounded by water, some sugar molecules diffuse through the membrane. This process is called *dialysis*. At the same time, some water molecules diffuse through the membrane into the sugar solution. This process is called *osmosis*. When sugar solution is put inside the bulb of a thistle funnel with its wide end closed by a membrane and standing in water, water diffuses inwards across the membrane (osmosis) and sugar diffuses outwards (dialysis) (see Fig. 31). The explanation of this is that the moving molecules of water and sugar are constantly hitting against the membrane, which behaves like a sieve with very tiny holes. The water molecules, being much smaller and moving more rapidly than those of sugar, find their way through the sieve much more easily, so that more water passes through the membrane into the sugar solution than sugar molecules pass outwards through the membrane into the water. Hence the level of the liquid inside the thistle funnel rises. Thomas Graham (1805–1869), while experimenting with this diffusion of dissolved substances through membranes, found that some substances, e.g. salt, sugar, urea, and glycerine, *dialysed* (or passed through membranes); while others, e.g. egg-white, starch, gelatine, and glue, did not dialyse. As the first class of substances crystallize readily, Graham called them *crystalloids*. The second class of substances, whose molecules are too big to pass through membranes, he called *colloids*. Animal and plant material consists of both crystalloids and colloids. For example, the proteins and starches are *colloidal* and so cannot pass through the walls of the small intestine until their large colloid molecules have been broken down into simpler, smaller, diffusible molecules of *crystalloids* (the amino-acids and simple sugars). (See page 256 for experiments on dialysis.)

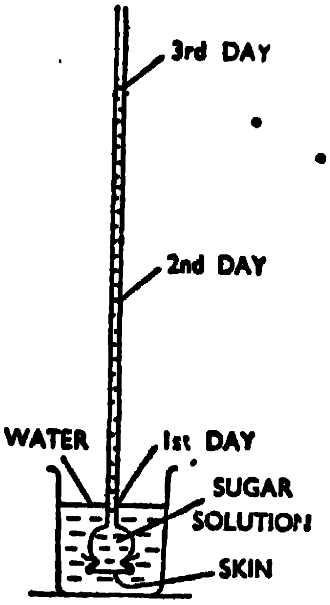


FIG. 31.—Osmosis

Digestion, therefore, prepares the food for absorption by converting the large molecules of colloids into the smaller molecules of crystalloids which can pass through the walls of the intestine.

Assimilation, and the functions of the liver

After absorption, the soluble food materials are carried by the bloodstream to the body-cells where respiration goes on and where the foods become part of the protoplasm, i.e. are '*assimilated*'. The food passes first, however, into the liver, all the veins from the food-canal joining together to form one large vein (the portal vein), which runs to the liver and there divides up into capillaries again. The liver is the largest gland in the body; it is situated in the body-cavity near the diaphragm and partly overlaps the stomach. Its most important function seems to be regulation of the composition of the blood; it is the great storehouse and laboratory of the body: for example:

1. All the sugar formed by the digestion of carbohydrates is carried by the portal vein from the small intestine to the liver. This sugar is usually in excess of immediate requirements and most of it does not pass straight through the liver to the tissues, but is *stored as glycogen* (or 'animal starch'). When the main blood-stream becomes less rich in sugar (e.g. after exercise), glycogen in the liver is reconverted to sugar, which passes into the blood. In this, and in other ways, the liver controls the amount of sugar in the blood.

2. The liver does not store sufficient sugar to keep a starving man's blood-sugar at normal level for long. But it can produce sugar in another way—by breaking down the amino-acids brought to it by the portal vein. These amino-acids, when in excess of immediate requirements, are *not stored* in the liver, but are broken down and liberate sugar and ammonia. The ammonia thus formed is converted in the liver by a complex process, involving its combination with carbon dioxide, to *urea*. This harmless neutral substance is passed into the blood-stream and is later *excreted* by the kidneys in the urine. Naturally, not all the amino-acids are broken down in this way—some pass through the liver and are used to build up proteins in other body-tissues. But it is important to realize that protein as well as carbohydrate foods can be used by the body as a source of the sugar used in respiration.

3. The liver produces *bile*, whose part in digestion has already been briefly discussed on p. 81.

4. Metabolism in the liver is very active and this organ is in fact one of the major sources of heat in the warm-blooded mammal.

CHAPTER 8

HYGIENE OF THE ALIMENTARY SYSTEM

DISORDERS OF THE DIGESTIVE SYSTEM

Now that we know something of the normal working of the alimentary system in health we can consider some of the ways in which the digestive organs may be disturbed during the digestion of food.

In the first place, it is very important to chew solid food thoroughly, *particularly starchy food*. We have seen that the enzyme, ptyalin, in the saliva begins the digestion of starch while it is in the mouth and that its action continues for some time after the food has reached the stomach. But if *lumps* of starchy food are swallowed without being chewed, their digestion by ptyalin will cease before the lumps are sufficiently reduced in size to pass through the pylorus into the duodenum. Hence the lumps of starchy food stay too long in the stomach, causing discomfort and sourness.

An ordinary meal is digested and passed on by the stomach in about four hours, hence a space of five or six hours between meals enables the stomach to complete its work and have a short rest before dealing with the next meal. Hence, eating too much, eating too frequently, and eating at irregular intervals may overwork the stomach and give rise to digestive disturbance. One simple remedy for this is to give the stomach a rest by not eating solid food for several hours and by washing out the stomach by drinking plenty of warm water.

The commonest disorder of the digestive system is *constipation*, when faeces remain too long in the rectum. Constipation may be caused by lack of muscular exercise (e.g. in office workers and others who sit down while working). Another cause is *faulty diet*, e.g. irregular meals, lack of *roughage* in the food, drinking insufficient water, inadequate chewing of food, lack of leafy vegetables and fresh fruits in the diet, and lack of vitamin B; all of these may lead to constipation. The movement of food through the intestine is brought about by peristalsis, i.e. by waves of muscle movements squeezing the semi-liquid food along (Fig. 32). This action is much more efficient when the intestine is fairly full, hence it is better to have a few good meals with several hours between them, rather than frequent small meals. This is one of the objections to the habit of eating between meals. Fibrous matter in the food (e.g. cellulose and fibres of fruits, green vegetables, and whole-grain cereals) absorbs liquid as it passes along the food-canal and so produces bulk, which provides a natural remedy for constipation caused by sluggish movements of the intestinal muscle-walls. A well-balanced diet should supply about 2 gm. of such indigestible fibre (or roughage) obtained in equal proportions from fruits, vegetables, and cereals. Drinking plenty of water (plain or flavoured) *between meals* also helps to prevent constipation.

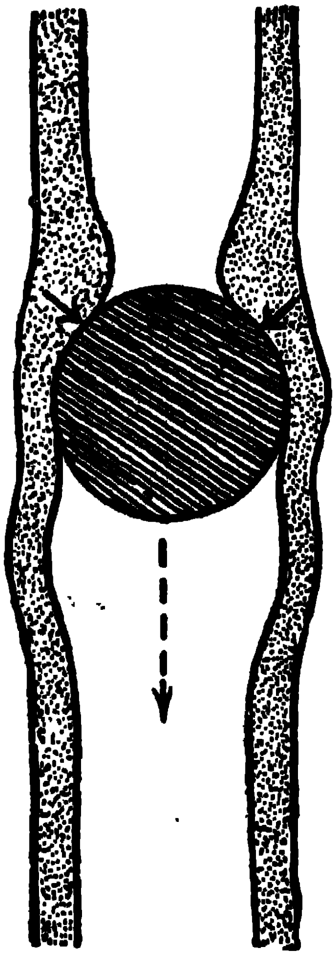


FIG. 32. — How food is squeezed along the food-canal

A regular daily evacuation (or motion) of faeces from the large intestine is one of the first essentials of good health. Irregularity in emptying the bowel is a common cause of constipation, for if the urge to defaecate (i.e. discharge faeces) is neglected the muscular walls of the rectum relax and the desire disappears. If the walls of the rectum are kept stretched in this way the muscles lose some of their power to contract and although a small quantity of faeces may be passed the rectum is not properly emptied at each motion. By using the latrine at the same time each day (preferably in the early morning) it is possible to establish a *regular habit* of emptying the bowel quickly, completely, and without strain. Muscular exercise helps to maintain regular and healthy working of the bowels by strengthening the muscular body-wall of the abdomen and thus keeping the digestive organs in their proper place in the belly-cavity.

To sum up, constipation may be avoided (*a*) by taking regular meals with plenty of fruit, green vegetables and whole-grain cereals, to supply 'roughage', (*b*) by taking regular exercise, (*c*) by drinking plenty of water between meals, (*d*) by making sure that the diet supplies sufficient vitamin B_1 (see also p. 62), and (*e*) by encouraging a regular habit of evacuating the contents of the large intestine *at the same time each day*.

The frequent use of *laxatives* (or 'loosening' medicines) is one of the commonest *causes* of habitual constipation, and they should only be used if prescribed by a doctor. Under no circumstances should an active laxative (or *purgative*) be given to anyone suffering from any sharp pain in the abdomen. In such cases there is always a danger that a strong purgative may burst the bowel and thus cause infection of the peritoneum (peritonitis), often with fatal results.

Even when all the digestive organs are healthy and in good working order, the digestive process may be upset by external factors, e.g. when a person is over-tired, frightened, or angry, the digestive juices do not flow freely, and indigestion may result if food is eaten by anyone in such a disturbed state. Conversely, a good appetite, pleasant company and happy surroundings, and the sight and smell of attractive food encourage the flow of saliva and other digestive juices necessary to good digestion.

PARASITES OF THE FOOD-CANAL

Intestinal worms

In tropical countries there are several kinds of worms which may enter the human food-canal and live as parasites in the intestine; in fact very few people are entirely free from such worms, which feed on the digested, semi-liquid food in their host's bowel. Such intestinal worms interfere with the absorption of food, *particularly in babies and young children*, causing a great deal of sickness and even death in many tropical countries, where more than 90 per cent. of the population may be infected with these parasitic worms. In fact, this is one of the main causes of 'backwardness' among individuals and communities in some 'under-developed' countries.

Infection is carried by contaminated food and by dirty hands and food-vessels, and we can guard against becoming infected with worms (*a*) by boiling any suspected drinking-water, (*b*) by not walking barefoot on mud or in dirty water, (*c*) by not bathing in dirty water, (*d*) by thoroughly cooking meat and vegetables, (*e*) by carefully washing raw fruit before eating it, avoiding any fruit whose skin is broken and, most important of all, (*f*) by improved sanitation (e.g. proper latrines) and cleanly habits.

Round-worms

The female round-worm (see Fig. 33) lays thousands of eggs, which may remain alive in damp soil for over a year. Fruit and vegetables often become dirty with soil containing round-worm eggs. If such fruit and vegetables are eaten raw without first being washed clean, then the eggs enter the food-canal and hatch out into round-worm *larvae* in the upper part of the small intestine. These larvae bore their way through the wall of the intestine and reach the portal vein, which carries blood to the liver. They are carried first to the liver and then to the lungs by the blood-stream. The round-worm larva then bores through into an air-sac and is coughed up the wind-pipe to the throat, down which it is swallowed for a second time to spend its adult stages in the small intestine. Adult round-worms may grow to a length of 20–40 cm., absorbing digested food from their host. Round-worms are easily killed and can be removed by a doctor with the aid of drugs.

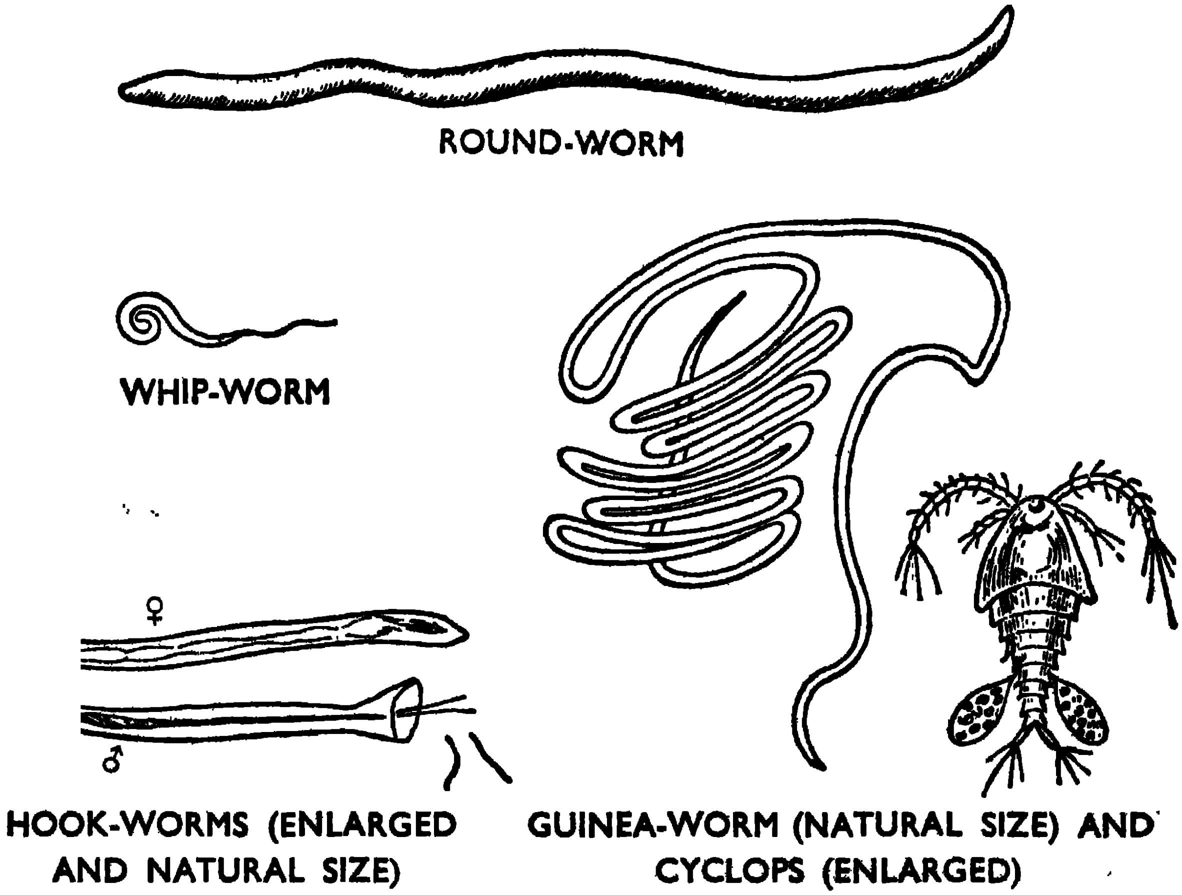

ROUND-WORM
WHIP-WORM
♀
♂
HOOK-WORMS (ENLARGED AND NATURAL SIZE)
GUINEA-WORM (NATURAL SIZE) AND CYCLOPS (ENLARGED)

Fig. 33.—Internal parasites of Man

♀ female; ♂ male

Round-worm larvae cause serious irritation to the stomach, small intestine and lungs, resulting in indigestion, constipation and faulty absorption of food. The intestinal walls are weakened and the abdomen swells (pot-belly); the patient fails to grow and gain weight. Children with worms very often have running noses. The stomach irritation sometimes causes a child to eat dirt and thus become further infected. All these factors cause stupidity and laziness in a child of good natural intelligence. Parents and teachers, therefore, should always be on the look-out for signs of worm-infection in children, and in suspected cases a small sample of the child's faeces should be sent to a hospital or clinic for examination under the microscope. If worm eggs are seen in the faeces (or 'stool') then proper medical treatment can be given to remove worms and their eggs from the infected person.

Drugs will remove worms from the body but will not *prevent* infection. Prevention of worm-infection (and other 'filth-diseases') is mainly a matter of *improved housing* and *proper sanitation*, e.g. by the provision of proper latrines. Health education is also necessary to encourage healthy habits and practices, e.g. washing the hands (*a*) after using the latrine, and (*b*) before taking food. Improved nutrition alone will not solve the worm-problem, since the intestinal worms feed on their host's food and irritate his food-canal so that it does not absorb food properly.

Thread-worms and whip-worms

Thread-worms do not multiply inside the intestine, but the female worm crawls out of the anus and lays thousands of eggs in the surrounding skin. This produces severe itching, which often leads to scratching, so that eggs get under the finger-nails and may be conveyed to the mouth. In this way more parasites are introduced into the food-canal. An itching nose also is a common sign of thread-worm infection.

Whip-worm eggs pass out with the faeces, and when such faeces are allowed to lie about on the ground and become dry, the tiny eggs are blown by the wind and may infect food-stuffs.

Proper medical treatment is necessary to remove thread-worms and whip-worms from the body.

Hook-worms

The most dangerous intestinal worm is the *hook-worm*, common in all warm countries (see Fig. 33). Hook-worms attach themselves to the wall of the intestine and suck blood, thus gradually weakening their host.

If there are a lot of hook-worms present in a man's intestine, and if no treatment is given, he becomes weaker and weaker and may die. The hook-worms lay eggs which pass out with the faeces, and if the eggs find their way into damp, warm earth they hatch out into tiny hook-worms.

These young hook-worms enter the intestine by a roundabout path.

If a man walks barefoot on infected soil the tiny hook-worms enter the skin and make their way into the *lymph-vessels*, whence they are carried to the main blood-stream. As the blood flows through the capillaries of the lungs, the tiny hook-worms bore their way through into the air-sacs and are coughed up from the air-passages. Many of them are swallowed and pass through the stomach into the intestine, where they attach themselves and suck blood from their host and mate, thus completing the life-cycle (see Fig. 34). A single hook-worm can remove 0·5 c.c. of blood per day, and as infection by a *thousand* worms is not uncommon, a heavily infected man may lose *several pints* of blood per day.

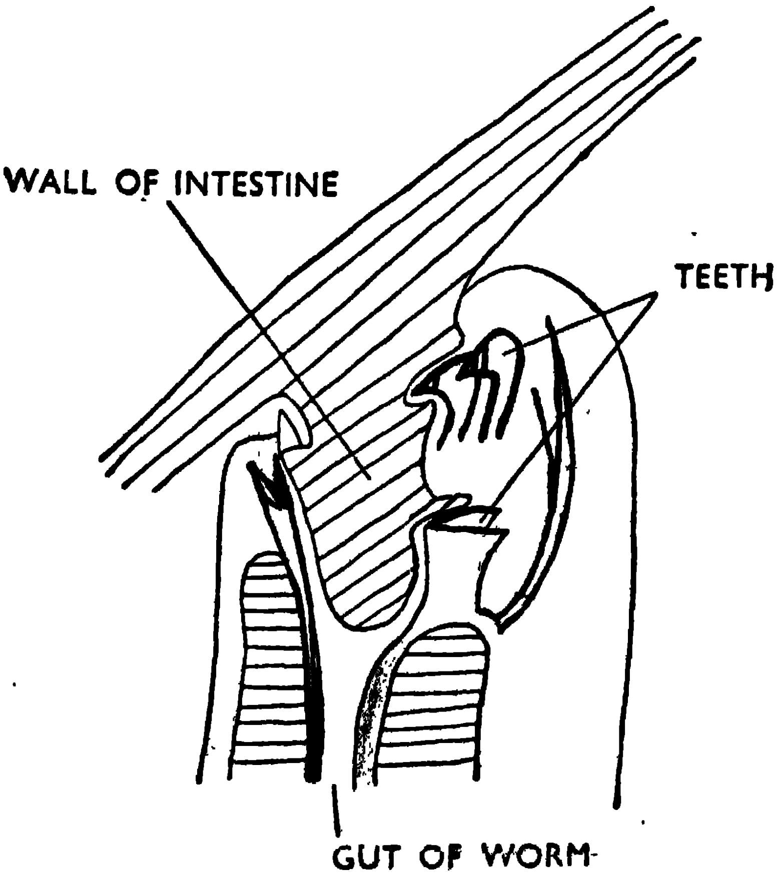


FIG. 34.—Head of hook-worm attached to wall of human intestine (diagrammatic and highly magnified)

People harbouring large numbers of hook-worm seem always tired and lazy; actually they are sick and need treatment. Fortunately, it is not difficult for a doctor to remove all the hook-worms from a man's intestine by a few doses of medicine, and re-infection can be prevented (*a*) by not walking barefoot, (*b*) by the proper disposal of faeces (so as not to infect the soil or water), and (*c*) by carefully washing the hands and feet soon after they have been in contact with the soil.

Tape-worms

A tape-worm looks like a piece of jointed white ribbon or tape, and may grow to a length of several feet (see Fig. 35). The 'head' attaches itself to the wall of the intestine and the worm absorbs digested food through its large surface as it floats in its host's intestine. Joints from the other free end of the tape-worm, full of embryos, break off from time to time and pass out with the faeces. If a pig swallows an embryo, it bores its way through the wall of this animal's intestine and enters its muscles, developing into a 'bladder-worm'. (This name refers to its shape and does *not* mean that it lives in the host's bladder.) If a man eats raw or under-cooked meat infected in this way, the bladder worms attach themselves to the wall of his intestine and develop into tape-worms, thus completing the life-cycle. In civilized countries meat and fish are examined by Health Inspectors before being offered for sale, and if it contains worms it is condemned and destroyed. In any case, if the meat is thoroughly cooked, such parasites will be killed.

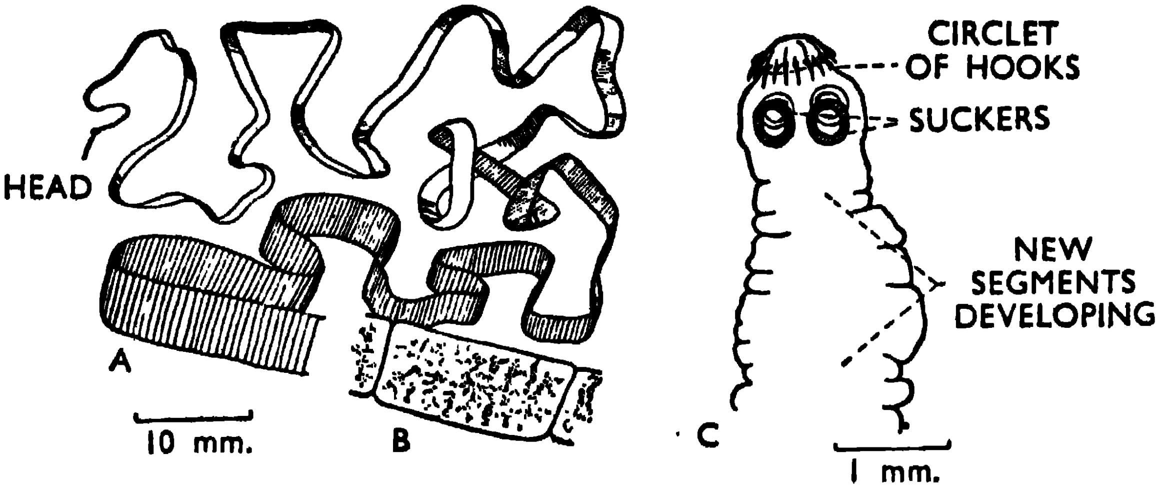


FIG. 35. Tape-worm

A—first few inches of a tape-worm several feet long (about natural size). B—ripe joint, containing eggs, from end of tape-worm (about natural size). C—head of tape-worm (× 10).

Guinea-worms

This parasite is common in some parts of Africa and India. The adult female guinea-worm (which may grow to a length of several feet) lies just beneath the skin, usually in the legs and feet, where it can be either seen or felt under the skin (see Fig. 33). The female worm then passes out a milky liquid containing enormous numbers of embryo worms, usually forming a white blister on the skin. These embryos escape into water (usually while bathing), and if they enter the body-cavity of their intermediate host—*Cyclops* (a small fresh-water flea)—they grow to a length of about 1 mm. in 4–6 weeks. If water containing infected water-fleas is swallowed by Man, the young guinea-worms are set free in the stomach and bore through the wall of the food-canal to complete their development in the human tissues. The female parasite only comes to the surface of the body in order to pass out the embryo worms. When a female guinea-worm appears under the skin, it should be removed in a hospital or dispensary and not by self-treatment. Guinea-worm infection can be prevented by boiling or filtering the drinking water to kill or remove the intermediate host—*Cyclops*. Public water supplies should also be protected from infection by guinea-worm patients.

INTESTINAL DISEASES

Dysentery, *typhoid*, and *cholera* are infectious intestinal diseases of the filth-borne type, because the organisms which cause these diseases enter the mouth along with food and water which have been contaminated by human filth. In fact, they are '*anus-to-mouth infections*' because these organisms do not exist outside the body except in material fairly recently contaminated by faeces from an infected person. So remember that every case of these intestinal diseases is caused by that person *swallowing excreta*. These diseases were formerly called 'water-borne diseases', because in the days before careful attention was given to public water supplies, infected drinking-water was the cause of serious outbreaks of these diseases.

House-flies often act as carriers of dysentery and typhoid, feeding on infected faeces and carrying the disease germs to human food. The germs may be carried sticking to the hairy legs of the fly (see Fig. 36) and also in its food-canal, where they can live for several days, being passed out either in the fly's faeces or in its vomit, since before a fly takes in its food it softens it by vomiting the contents of its crop. An average house-fly carries over a million bacteria (though not all harmful ones). It is therefore most important to protect all food from flies and also, by the sanitary disposal of refuse, to stop flies from breeding (see p. 223).

Dysentery

Dysentery is a disease of the large intestine caused by dysentery bacteria (bacterial dysentery) or by an organism larger than bacteria—the dysentery *amoeba* (causing amoebic dysentery). Motions become frequent and the faeces become watery and mixed with blood and mucus. There is often severe pain in the abdomen. Microscopic examination of the stool is necessary to identify the cause of the disease, and early medical treatment should be sought. In the meantime, no solid food should be taken but *plenty of liquid* (to make up for all the water lost in the stool), e.g. weak tea (hot or cold), rice-water, barley-water, Marmite in water, or beef-tea or chicken-tea.

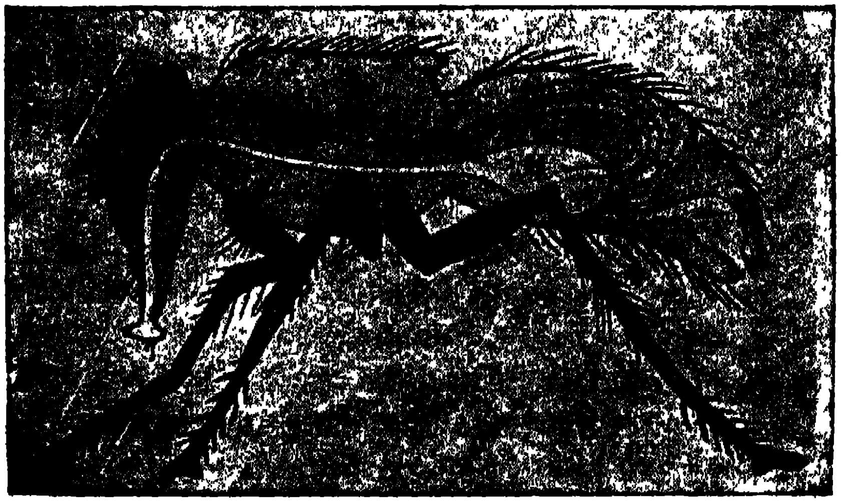


FIG. 36.—Section through house-fly (diagrammatic and highly magnified) showing sucking-tube and crop—H; also hairy legs

The organisms causing dysentery are passed out along with the patient's faeces, hence the only effective way of stopping the spread of the disease is the proper disposal of infected faeces, so that water supplies and foodstuffs are not infected (and so that flies cannot get at faeces).

Dysentery usually comes from one's own home or from one's immediate community, so one usually knows of nearby cases and can take special precautions, being particularly careful to drink only boiled water and milk, to cook all vegetables, to wash carefully any fruit which is to be eaten raw and to protect food from flies and cockroaches. (*N.B.* It is particularly important that no one suffering from the slightest persistent looseness of the bowels, or recovering from this disorder, should be allowed to handle other people's food or food-vessels.) People are sometimes infected with dysentery organisms without feeling unwell, and if such 'healthy carriers' are dirty in their habits, and, especially if they handle food supplies, they may be very dangerous to others. Amoebic dysentery is particularly dangerous from this point of view because the patient may have the dysentery amoeba in his bowel for a long time without knowing it.

Typhoid fever

Typhoid fever and the less dangerous *para-typhoid fever* are both diseases of the small intestine. In typhoid fever, sores are formed in the intestine, and the great danger is that a sore may burst and make a hole in the wall of the intestine, causing death. Hence the patient must not be given any solid food until he has recovered from the disease. New drugs have revolutionized the treatment of typhoid and the sooner a fever-patient is examined by a doctor the better.

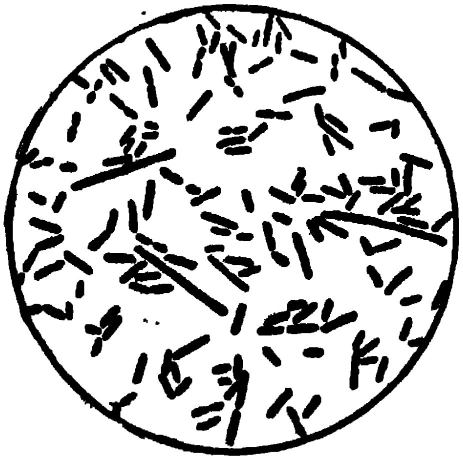


FIG. 37. — Typhoid bacteria (highly magnified)

Copyright, by permission of Burroughs Wellcome & Co. (The Wellcome Foundation Ltd.)

Typhoid bacteria are present in the faeces and sometimes in the urine, saliva, or sweat of the patient, hence the greatest care must be taken in disposing of infected faeces and in washing the patient's clothing and bed-clothes, so that the typhoid bacteria cannot get into food or drink. To avoid catching typhoid one should drink only purified or boiled water and ensure that all foodstuffs (particularly milk) have been protected from dirt and insects. Living typhoid bacteria have been found on, or in, house-flies three weeks after the flies have been in contact with infected faeces (see Fig. 36).

Typhoid and para-typhoid bacteria can live in ice, which should not be put *into* drinks unless it is known to be made from pure water.

Another way in which typhoid can be spread is by the 'healthy carrier', the person who seems to be healthy although he carries typhoid germs in his bowel and may discharge them when his bowels are opened. If such 'healthy carriers' are not discovered and prevented from handling food as cooks, food-hawkers, ice-cream sellers, &c., and *if they do not wash their hands properly after using the latrine*, they may convey infected material to other people's food. Many typhoid *epidemics* (or sudden outbreaks) have been caused in this way, and public health authorities are always on the look-out for such carriers. When an epidemic breaks out, if one particular person is found to have been in contact with the food of all the patients, his stool is examined by the health authorities, and if this is found to contain typhoid bacteria, the man is not allowed to work in any food-handling business.

Protection against typhoid fever is given by injecting killed typhoid bacteria under the skin, in three doses, at intervals of about a week. This anti-typhoid inoculation is harmless and gives protection against the disease for about a year. The most important factor in preventing outbreaks of typhoid fever is, however, proper sanitation and clean personal habits, particularly after using the latrine.

Cholera

Asiatic cholera is a very infectious intestinal disease and is perhaps the most terrible of all tropical diseases, for over 50 per cent. of those that get the disease die from it unless treated. About two days after infection, the patient has very frequent watery motions for a few hours; he then becomes unconscious and, in most cases, dies. In this way, the disease may kill hundreds of people in a few hours.

With such a terrible disease, *prevention* is the most important thing, and as in the case of the other intestinal diseases, the only way of becoming infected is to swallow the disease organisms. In countries where cholera is common, it is nearly always spread in drinking-water, hence the first step towards preventing cholera is a pure public water supply. If the disease appears, the patients must be taken to an 'isolation hospital' at once, so that proper treatment can be given; and care must be taken to destroy infected faeces and to disinfect everything used by the patient. At the same time healthy persons in the community must continue the usual boiling of all water and milk, the thorough cooking of all meat and vegetables, the protection of all foodstuffs and food utensils from insects, and the washing of hands in boiled water before handling any food. Cholera can be completely controlled by proper sanitation.

APPENDICITIS

Appendicitis is an inflammation[1] of the *appendix*, the small, blind-ended tube (about the size of a finger) which opens out of the *caecum*, i.e. the beginning of the large intestine (see Fig. 38). In plant-eating mammals, the appendix is very large and plays an important part in digesting cellulose, but in Man it appears to be useless and even a source of danger, particularly to people who eat a lot of meat. Tenderness or pain in the lower part of the belly region, often on the right side, is a common sign of appendicitis, and in such cases *it is most important not to take purging medicine*, e.g. castor-oil or 'salts', because this produces violent movements of the intestine and may cause the inflamed appendix to burst, with very serious results. If belly-pains are frequent or lasting, a doctor should be consulted as soon as possible, before taking food or medicine, because self-treatment is responsible for many deaths through appendicitis. *Early* treatment (which sometimes involves removal of the diseased appendix by a surgeon) will prevent many deaths through appendicitis. Appendicitis is *not* caused by swallowing small seeds when eating fruit. It is usually caused by the appendix becoming infected with *pus-forming bacteria* (see also p. 160).

---

[1] *Inflammation* is a medical term which is often used in everyday life without any clear idea of its meaning. When any part of the body becomes hot, swollen, painful, and red, it is said to be *inflamed*. Such inflammation is usually a sign of bacterial infection, showing the natural protective action of the body in trying to get rid of the cause of the disturbance, to limit its action, and to repair any damage. For example, when the skin is broken and pus-forming bacteria enter a wound,

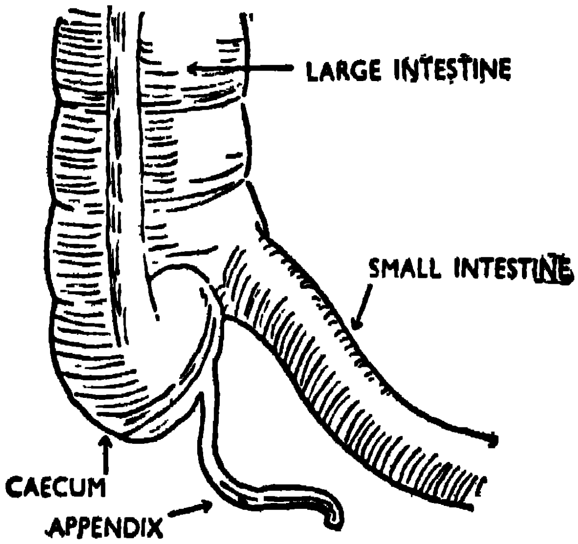


FIG. 38.—Human appendix

---

there is an increased supply of blood to the damaged area of the skin, bringing more white blood-cells to deal with the invading bacteria. This increased supply of blood causes a local rise of temperature, redness and swelling in that part. The increased pressure on the sensitive nerve-endings in this part of the skin causes pain and tenderness. Inflammation itself is not a disease, but a sign of the body's reaction to infection. This natural resistance often overcomes the invading organisms and their harmful products without outside help in the form of medical treatment.

CHAPTER 4

THE RELEASE OF ENERGY DURING RESPIRATION

INTERNAL RESPIRATION

In Chapter One we considered the mechanism of *breathing* (or *external respiration*) in Man. This type of breathing is characteristic of *mammals*, which are the only animals with the air-tight chest-cavity necessary for breathing by this method.

Oxygen diffuses into the blood-capillaries through the thin membrane lining the air-sacs and combines with the haemoglobin of the red blood-cells.

This oxygenated arterial blood finally reaches the capillary blood-vessels of the body-circulation. In these thin-walled capillaries, the oxy-haemoglobin gives up its loosely-combined oxygen to the tissue-fluid, which escapes through the walls of the capillaries and bathes the individual body-cells. *The essential feature of respiration—the actual setting free of energy—takes place in the individual body-cells.* (This is called *internal respiration*, or *tissue-respiration*.) In the living cell, the food-substance that is oxidized to set free energy is always a simple sugar (usually *glucose*) and the oxidation is brought about by *enzymes* present in the cell. Besides setting free

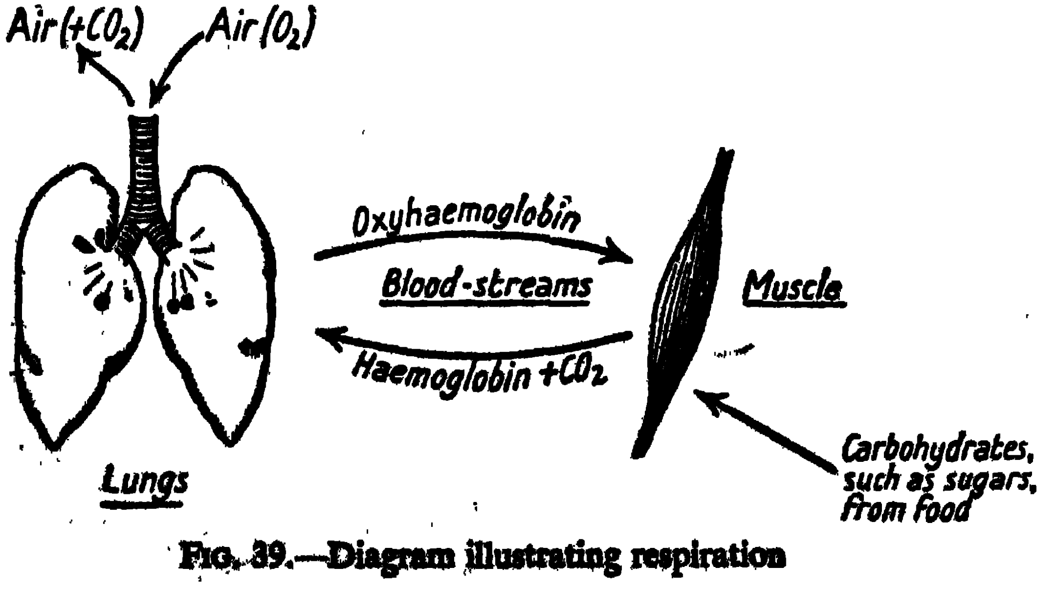


FIG. 39.—Diagram illustrating respiration

energy, this oxidation also produces carbon dioxide and water, which diffuse out of the cell into the tissue-fluid and so back to the blood-capillaries and veins. On reaching the lungs, the carbon dioxide and water diffuse into the air-sacs and are got rid of during breathing (see Fig. 39).

BODY TEMPERATURE

Animals are sometimes classified as either *cold-blooded* or *warm-blooded.* The temperature of the blood of fishes, frogs, and snakes, for example, changes with the temperature of their surroundings, and as these animals often feel cold to the touch, they are said to be cold-blooded. This is a misleading term, since the blood of a snake lying in hot sunshine may rise to a high temperature. 'Animals of *variable* temperature' would be a better term for such creatures. In contrast, the warm-blooded animals, the birds and mammals, should be called 'animals of constant temperature', for they are able to keep their blood (and therefore their bodies generally) at a remarkably constant temperature, whatever that of their surroundings may be. A man's blood, for example, is always between 97° and 99° F. (usually 98·4° F. = 37° C.) when he is healthy, whether he is living near the Equator or near the Arctic circle. The average temperature of a bird is even higher; 106° F. (= 41° C.).

This constant high temperature is a great advantage to birds and mammals, since it enables them to be equally active (e.g. in getting food) under different external conditions. We have seen that an animal gets its supply of energy by oxidizing sugar and that this chemical change goes on, with many others, in the body-cells. These chemical changes are more rapid at higher temperatures; thus muscular action is more rapid when the body-temperature is reasonably high. In a cold winter most of the land animals of variable temperature *hibernate*, that is, they pass into a kind of prolonged sleep which usually lasts throughout the cold period. During this time of inactivity they are able to survive without eating or drinking for some months. They become active again when the temperature rises.

Most mammals and birds remain active throughout even very cold winters and they are able to do so because of their constant body-temperature.

Regulation of body-temperature

If the temperature of the body is to be kept steady between 97° and 99° F. there must be a close balance between heat gain and heat loss.

The body *gains heat* from two sources: (*a*) from the heat produced during *internal respiration* and (to a smaller extent and under certain conditions described below) (*b*) from its surroundings. We have seen, on pp. 52–53, that heat production due to respiration is about 1 Calorie per kilogram of body-weight per hour, when resting, and that the amount of heat produced is increased by increased muscular activity. If there was no heat loss from the body, the body-temperature would rise about 1° C. (= 1·8° F.) per hour under resting conditions and it would rise still more rapidly during exercise. But our mechanism for temperature regulation is so efficient that the body-temperature is kept very nearly the same at all times. It is only during very strenuous exercise or when the surrounding air is much hotter than the body and nearly saturated with water-vapour that heat is lost too slowly to preserve the normal body-temperature in a healthy person. Most of the heat gained by the body is produced inside the body-cells during respiration and is carried to all parts of the body by the blood-stream. Since respiration goes on continuously, the body is always receiving heat from this internal source. The body can also take in heat from external sources under certain conditions, e.g. when the surrounding air-temperature is higher than the skin-temperature or when the body-surface is exposed to sunshine, but such external sources supply much less heat to the body than it gets from internal respiration.

The body *loses heat* mainly from the *skin*, though some body-heat is also lost during breathing (as will be explained later in this chapter). Three distinct physical processes are responsible for heat loss from the skin. In order of their relative importance under tropical conditions, these are (i) by *evaporation of water* from the skin, (ii) by *radiation* from the body-surface to cooler neighbouring objects, and (iii) by *conduction* and *convection* to the surrounding atmosphere when the air-temperature is lower than that of the skin. These methods of heat loss require further explanation.

(i) *Heat loss by evaporation of water*

The main factor in heat loss at high temperatures, or when the muscles are in very active use, is evaporation of water from the skin. Even under cool conditions, the skin is always giving off a little water-vapour, but under hot conditions, or when hard muscular work is being done, large quantities of water are lost as *sweat*, sometimes as much as a litre in an hour. This sweat escapes from the *sweat-pores* in the skin. It is formed in knots of coiled tubules—*sweat-glands*—deep down in the skin, and it passes along the *sweat-ducts* to the *sweat-pores* (see Fig. 20).

Sweat is mainly water, and the sweat-glands remove this water from the blood as it flows through the skin. The evaporation of 1 gm. of water from the skin at 97° F. requires about 0·58 Calories (= 580 'small calories') of heat (see p. 275). Most of this *latent heat* (see p. 276) is taken from the skin itself, thus cooling it. Hence the more sweat *evaporated from the skin* the more heat lost by the body. Since evaporation is more rapid in moving air than in still air, a current of air 'feels cooler' than still air of the same temperature and humidity. It is important to realize, however, that sweating can have no cooling effect unless the sweat evaporates. When drops of liquid sweat remain on the skin without evaporating, there is great discomfort owing to the lack of any cooling effect. This is why a hot, damp atmosphere, almost saturated with water-vapour, is so much less comfortable than a dry atmosphere *at exactly the same temperature.*

Heat is also lost by evaporation of water from the moist surfaces of the lungs and air-passages during breathing, but the amount of heat lost in this way is not affected by changes in the external temperature until *panting* begins, exposing a larger surface area of the tongue and mouth cavity and changing the air more frequently by rapid, shallow breathing. Panting provides an important method of heat loss among mammals with thick fur and few sweat-glands, e.g. dogs. A dog pants very rapidly under hot external conditions or after strenuous exercise and thus increases heat loss by evaporation of water from the tongue and from the surface of the mouth cavity.

(ii) *Heat loss by radiation*

Radiation is the transfer of heat from one object to another *without any physical contact between them.* For example, the sun radiates heat to the Earth through the empty space that exists outside the earth's atmosphere, the sun's heat-waves travelling in the same way as its light-waves and with the same speed (186,000 miles per second). Whenever two neighbouring objects are at different temperatures, heat is *radiated* from the surface of the hotter object and is *absorbed* through the surface of the cooler object, and the greater the difference in temperature the greater the amount of heat exchanged. The human body radiates heat to every cooler object in its neighbourhood, e.g. to the furniture, walls, floor, and ceiling of a room, and this is the main factor in heat loss from the body *at low temperatures.* When the air-temperature is between 70° and 80° F. (= 21° to 27° C.) about two-thirds of the total heat loss takes place by radiation, but once the air-temperature exceeds the skin-temperature, then there can be no cooling by radiation, only by evaporation of water from the skin.

(iii) *Heat loss by conduction and convection*

Conduction is the transfer of heat to any cooler substance *in contact* with the body, e.g. air which covers the skin and air which enters the lungs and air-passages during breathing receives heat from the body *by conduction* if the external atmosphere is below body-temperature. Conduction is a much less important means of heat loss than either evaporation or radiation. The skin of most mammals is covered by hair or fur which entraps air to form a heat-insulating coat. Man has little body-hair and in cold climates he prevents heat loss by wearing clothes which maintain a layer of air (a bad conductor) next to the skin. A layer of fat under the skin has a similar effect.

Convection is the transfer of heat along with *moving* gases or liquids, and this process accompanies conduction in removing heat from the skin. Cool air in contact with the skin is warmed by conduction, expands, becomes 'lighter', and therefore rises upwards. Cool air flows in to take the place of this warmed air, producing a *convection current* of air which conveys heat away from the body. Cooling by convection is increased by exposure to moving air, since air in contact with the skin (and thus warmed by conduction) is swept away more rapidly, carrying more heat with it. Heat loss by conduction and convection is greater when the external air-temperature is low. As the air-temperature rises, less and less heat is lost by these processes, until, when the air-temperature exceeds the skin-temperature, there is no further heat loss by conduction and convection.

Heat is lost mainly from the skin surface. But this heat was produced in the deeper tissues during respiration and has been brought to the surface of the body by the blood-stream. So the amount of heat brought to the surface depends on the rate at which blood flows through the skin. When the branch arteries supplying blood to the skin-capillaries contract, less blood reaches the skin and less heat is brought to the surface. Conversely, if the diameter of these blood-vessels increases, more blood will flow through the skin, bringing more heat to the surface and making the skin warmer. These changes in diameter of blood-vessels in the skin are delicately controlled by part of the brain that is sensitive to small changes in the temperature of its blood-supply.

When the external atmosphere is cooler than the body-temperature heat is lost from the lungs by warming inspired air to body-temperature. The cooler and drier the air the greater this heat loss through the lungs.

CHAPTER 5

THE NERVOUS SYSTEM

All living things respond to outside influences, i.e. they are *sensitive* to changes in their surroundings (which are called *external stimuli* [1]) and they can adjust themselves to what is happening around them by making suitable *responses*. In order that a *stimulus* shall produce the response which will be of most benefit to the animal concerned, there must be co-ordination. There are, therefore, three factors in behaviour: (*a*) *the reception of an external stimulus*, (*b*) *an active response to that stimulus*, and (*c*) *adjustment of the response to the stimulus.*

In the highest animals there are very sensitive arrangements in the complicated nervous system for receiving external stimuli and for producing rapid responses to such stimuli, and in Chapter One we studied the *central nervous system* in broad outline and saw that it consists essentially of the *brain* and *spinal cord.* This central portion of the nervous system is well protected by the skull and backbone.

The *central canal*, which runs from end to end of the spinal cord, opens out into a number of cavities inside the brain, and both the central canal and the brain-cavities are filled with liquid. As a young vertebrate animal develops from the fertilized egg-cell, the spinal cord is the first part of the central nervous system to develop, and then the anterior end of the spinal cord begins to swell out to form the brain Three swellings are formed in all young Vertebrates—the *fore-brain*, the *mid-brain*, and the *hind-brain.* From the primitive *fore-brain* develop the two halves of the *big brain* (cerebrum). The more highly developed the big brain, the more intelligent the animal, since this part of the brain is the seat of all voluntary action and conscious sensation. The most characteristic feature of the human brain is the exceptionally large *big brain.* The *mid-brain* controls the eye-muscles and it is also concerned with the control of *posture*, i.e. the way in which the body is carried. The *hind-brain* develops into the *spinal bulb* (medulla) and the *little brain* (cerebellum). The *spinal bulb* controls the unconscious movements of breathing, movements of the digestive organs,

---

[1] Singular—stimulus.

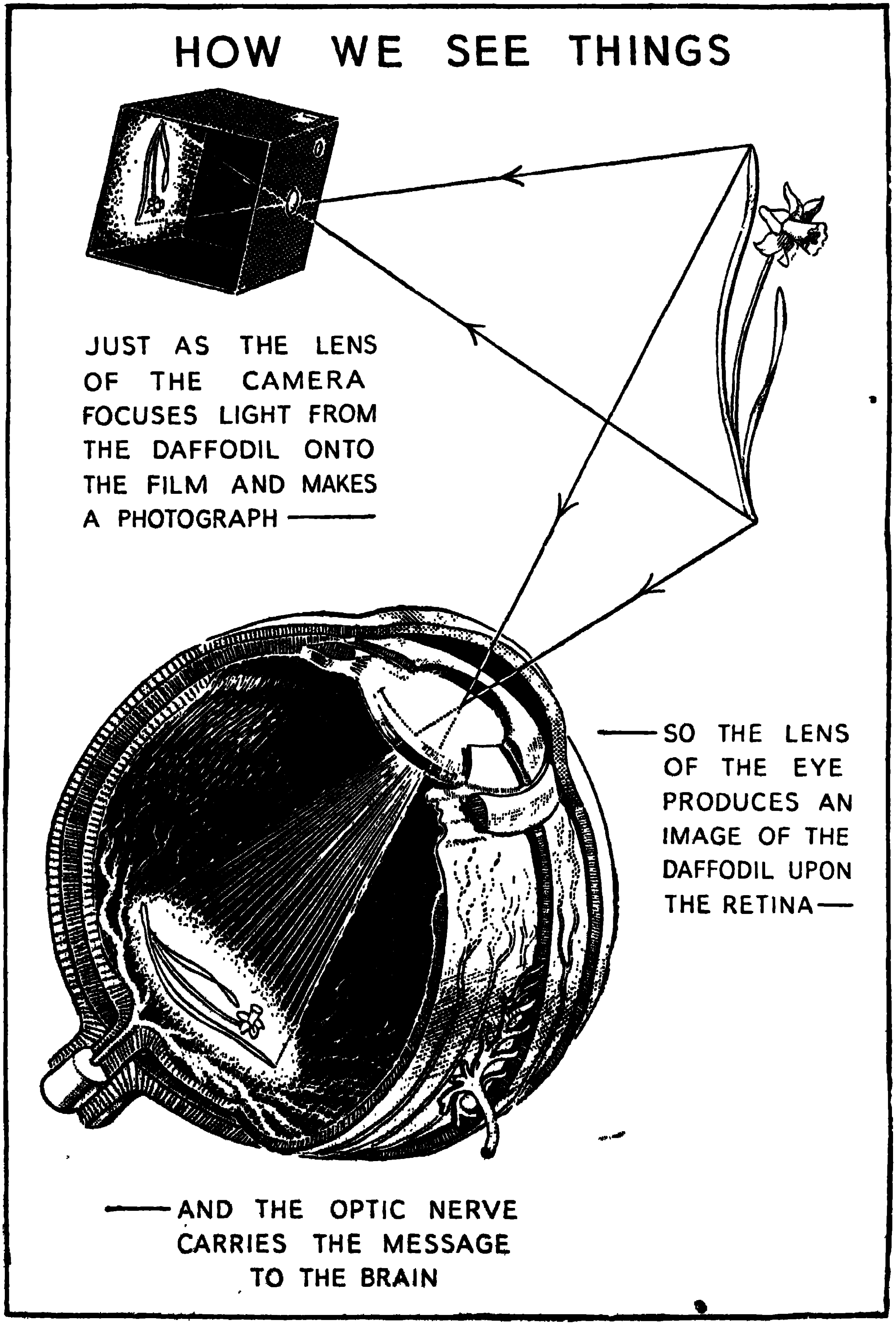

HOW WE SEE THINGS
JUST AS THE LENS OF THE CAMERA FOCUSES LIGHT FROM THE DAFFODIL ONTO THE FILM AND MAKES A PHOTOGRAPH ——
—— SO THE LENS OF THE EYE PRODUCES AN IMAGE OF THE DAFFODIL UPON THE RETINA ——
—— AND THE OPTIC NERVE CARRIES THE MESSAGE TO THE BRAIN

FIG. 40.—How we see things

heart-beat, and the activity of certain glands. The little brain appears to co-ordinate the action of all the different muscles concerned with movement, receiving messages from the organs of *balance* and from sense-organs in the muscles and joints (see also p. 112). A mammal with a damaged cerebellum can no longer balance its body and is unable to stand up.

THE SENSE-ORGANS

An animal's behaviour depends mainly on what is happening in the outside world around it. For example, when an animal sees food it makes the movements necessary to capture it, or if it hears a frightening noise from one direction, it moves away in another direction. A vertebrate animal gets information about what is going on in the outside world by way of the *eyes*, the *ears*, the *nose*, and by way of sensitive cells in the *skin*. Sensory nerves carry impulses from the *sense-organs* and the sensitive cells to the central nervous system.

The eye

Rays of light enter the eye through the *pupil*, and the *eye-lens* forms an image on the *retina*, the sensitive layer at the back of the eye (see Figs. 40 and 41). Branches of the nerve of sight run to all parts of the retina, and these nerve-fibres end in sensitive nerve-cells. When light falls on the sensitive nerve-

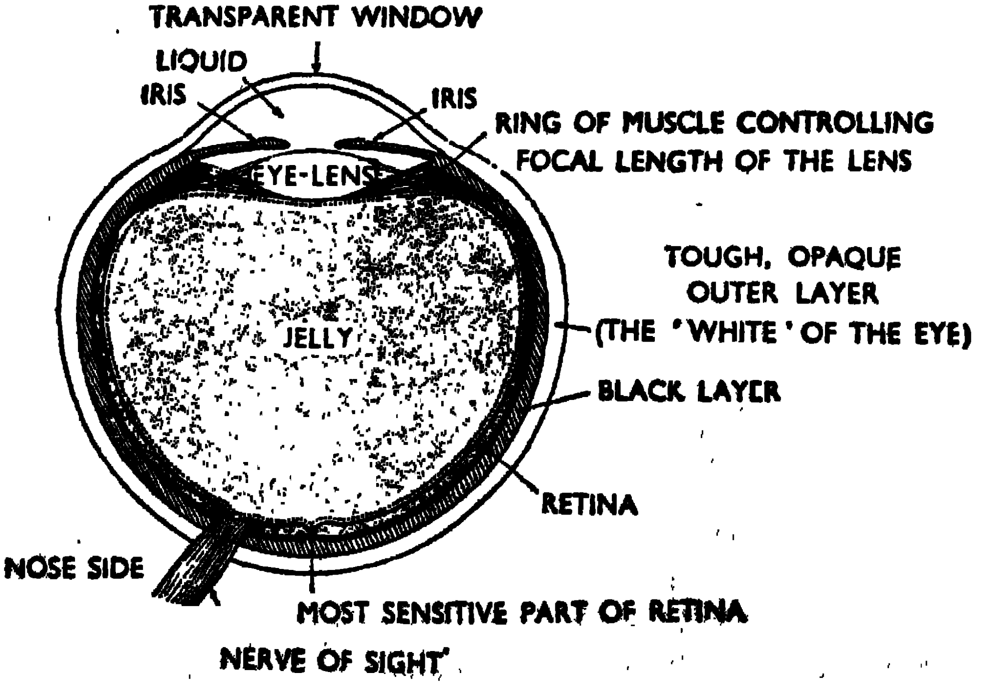

TRANSPARENT WINDOW
LIQUID
IRIS
IRIS
RING OF MUSCLE CONTROLLING FOCAL LENGTH OF THE LENS
EYE-LENS
TOUGH, OPAQUE OUTER LAYER (THE 'WHITE' OF THE EYE)
JELLY
BLACK LAYER
RETINA
NOSE SIDE
MOST SENSITIVE PART OF RETINA
NERVE OF SIGHT

FIG. 41.—The right eye in horizontal section (diagrammatic)

cells of the retina, impulses travel along the nerve of sight to a special part of the brain, and the animal becomes conscious of seeing something. The *eyeball* rests on a cushion of fat in the *eye-socket*, a bony cavity, and it can be turned up and down, and from side to side, by six flat strips of muscle. The front of the eyeball is transparent and it is kept wet by a watery liquid ('tears') produced from a small *tear-gland* in the outer corner of the eye-socket. In this way, the transparent window in front of the eye (the *cornea*) is washed each time the eyelids are closed and opened, the excess of 'tears' draining into the nose-cavity through a tiny duct which opens at the inner corner of each eyelid. (In crying, uncontrolled laughing, and violent coughing, the tear-gland produces more liquid than this tiny duct can drain away into the nose, and tears roll down the cheeks.)

The *iris*, a circular sheet of coloured muscle, corresponds to the '*stop*' of a camera, since it can expand or contract and thus change the size of the *pupil* (the opening in the middle of the iris). In this way the amount of light entering the eye can be controlled. If you stand in a shady place with your back to the light, and watch one of your eyes in a hand-mirror, you will see that the pupil is large, so as to admit plenty of light. If you then turn to face the light you will see the iris contract. This reaction protects the delicate retina and its sensitive nerve-cells from the shock of a sudden change in the amount of light that enters.

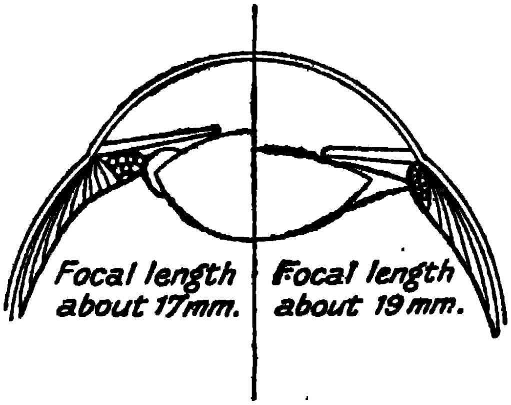


FIG. 42.—How the eye-lens changes its focal length

The part of the eye in front of the eye-lens is filled with a watery liquid. Immediately behind the iris is the double-convex *eye-lens*, a transparent, elastic body. In mammals, the curvature of this lens can be changed by movements of rings of muscle at the circumference of the lens, so that the lens can focus light rays from both close and distant objects to produce a clear image on the retina (see Fig. 42). In human beings these focusing arrangements sometimes go wrong and suitable lenses ('glasses' or spectacles) have to be worn in front of the eyes. The large space between the lens and the retina is filled with a transparent jelly-like substance.

The eyeball is enclosed by a tough, fibrous outer wall, lined with a black, non-reflecting layer except in front, where the outer layer also is thin and transparent.

Examination of eye

Examine the eye of an ox, sheep, or goat obtained from the abattoir. Notice that, except in front, the eyeball is surrounded by fat, which forms a protective cushion in the bony eye-socket. Carefully remove as much of this fat as possible and identify (*a*) the six *eye-muscles*, (*b*) the *nerve of sight* (*optic nerves*).

With scissors, or a sharp knife, separate the front half of the eye from the back half and identify (i) the front *cavity*, filled with a watery liquid, (ii) the rear *cavity*, filled with a jelly-like substance (you may be able to remove this, together with the eye-lens), (iii) the *eye-lens*, (iv) the *iris*, (v) the *pupil*, (vi) the tough, white, outer *layer* (*sclerotic*), (vii) the thin *black lining* (*choroid*) and (viii) the thin grey *retina* (which can be peeled off with care).

Examine an eye which has been hardened in 40 per cent. formaldehyde overnight, and then cut it in two, from front to back, in vertical section. Make a diagram of what you see. Also examine an eye-lens which has been removed undamaged.

The ear

In Man, as in most other mammals, the visible *external ear* is a gristly structure that serves to collect sound-waves and direct them down a tube on to the *ear-drum*. Some mammals, e.g. the horse and rabbit, can actually turn the external ear so as to collect sounds coming from different directions. (The horse, which moves its external ears a lot, has 17 muscles for moving each ear; Man has only 9 such muscles and they are all useless, except in rare cases.)

A narrow, slightly curved tube (about one inch long in Man) leads inwards from the external ear to the *ear-drum* (see Fig. 43). This tube is lined with outward-projecting hairs and wax-producing glands that help to protect the ear-drum from insects and harmful solid matter. The ear-drum consists of a very thin membrane (only a few thousandths of an inch thick in Man) stretched across the inner end of the tube leading from the external ear. Being so very thin, the ear-drum is easily damaged.

The rest of the ear—the *internal ear*—is entirely enclosed in the bone of the *ear-cases*, which form part of the skull. The *internal ear* is divided into two parts: (*a*) the *middle ear*, and (*b*) the *inner ear* (see Fig. 43).

The *middle ear* is a cavity in the bone of the skull, filled with air, and connected to the back of the throat by a narrow passage. By means of this tube (the 'Eustachian tube') the air on the inner surface of the ear-drum is kept at the same pressure as that of the air on its outer surface. (You can now understand why, in wartime, people are advised to keep the mouth open when bombs are falling nearby. This enables the sudden increase of air-pressure to act on both sides of the ear-drum, thus saving this thin membrane from being burst inwards.)

A *chain of three small bones*, hinged together, stretches across the middle ear and carries vibrations from the ear-drum to the *inner ear*, which contains the true *organ of hearing*. The external ear and the middle ear, therefore, are only concerned with receiving sound-waves and passing them on to the inner ear. (The *inner ear*, however, contains something besides the organ of hearing: one part of it is the organ of balance and position, which we shall discuss later.) There are two small openings, closed by membranes, between the middle and the inner ear. They are called the *oval window* and the *round window* (see Figs. 43 and 44).

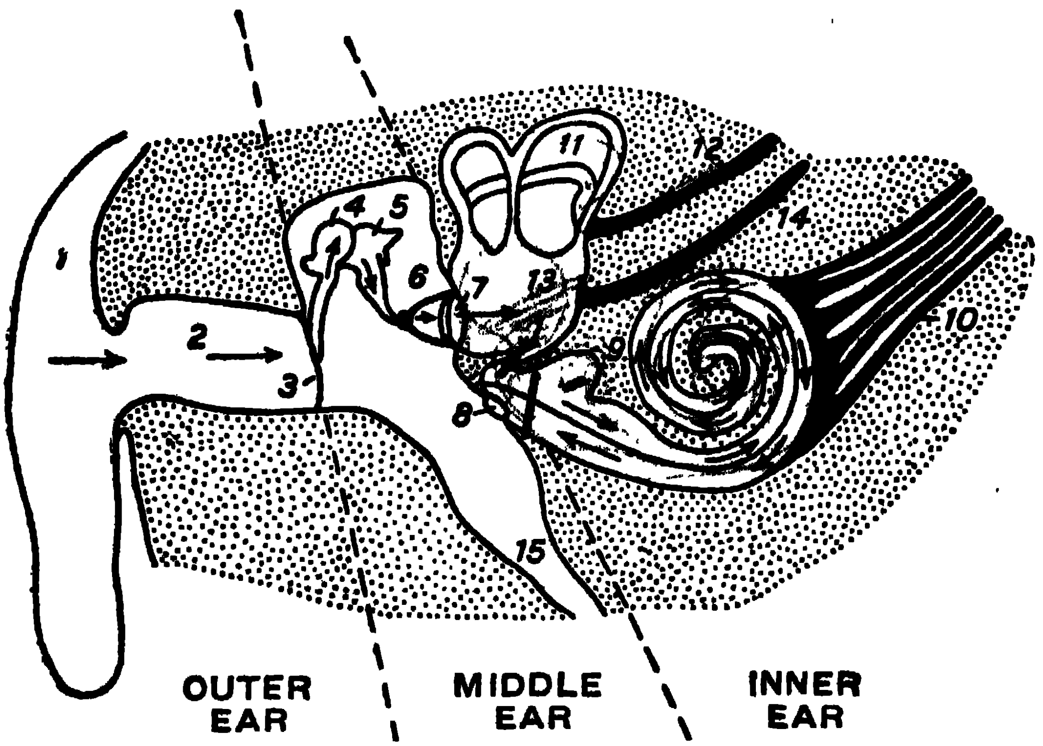


FIG. 43.—Vertical section through right ear (diagrammatic)

1—external ear. 2—tube leading to ear-drum. 3—ear-drum. 4, 5, 6—chain of bones. 7—oval window. 8—round window. 9—organ of hearing. 10—nerves of hearing. 11—semicircular canals. 12—nerve of sense of direction of movement. 13—organ of balance. 14—nerve of sense of balance and position. 15—tube leading to throat.

The actual organ of hearing consists of a spirally-coiled passage shaped like a tiny snail-shell and filled with a liquid; it is called the *cochlea*. The vibrations of the ear-drum are passed on and magnified by the chain of bones across the middle ear to the membrane of the oval window and similar vibrations are set up in the liquid filling the *cochlea.* These vibrations travel through the liquid up to the top of the spiral tube and then down again to the round window. (Hence, liquids being incompressible, as the oval window moves inwards the round window moves outwards.)

Embedded in the elastic membrane separating the two halves of the spiral tube (Fig. 45) are about 24,000 tiny fibres varying in length and tension. The largest of these is only $\frac{1}{16}$ inch long. This part of the ear has been compared to a minute but very complicated piano (without the keys), and it is supposed that, when the liquid in the spiral tube vibrates, those fibres 'in tune' will vibrate, too, in sympathy (i.e. they will *resonate*), and transmit tiny electrical impulses to the brain. The brain recognizes these impulses as notes of varying pitch according to the particular nerve fibres which carried them. 'Within the small volume of the *cochlea* lie 24,000 minute electrical machines and from it emerges a cable of 24,000 conducting nerves. This machinery is so complicated that science has not yet completely discovered its workings.'[1]

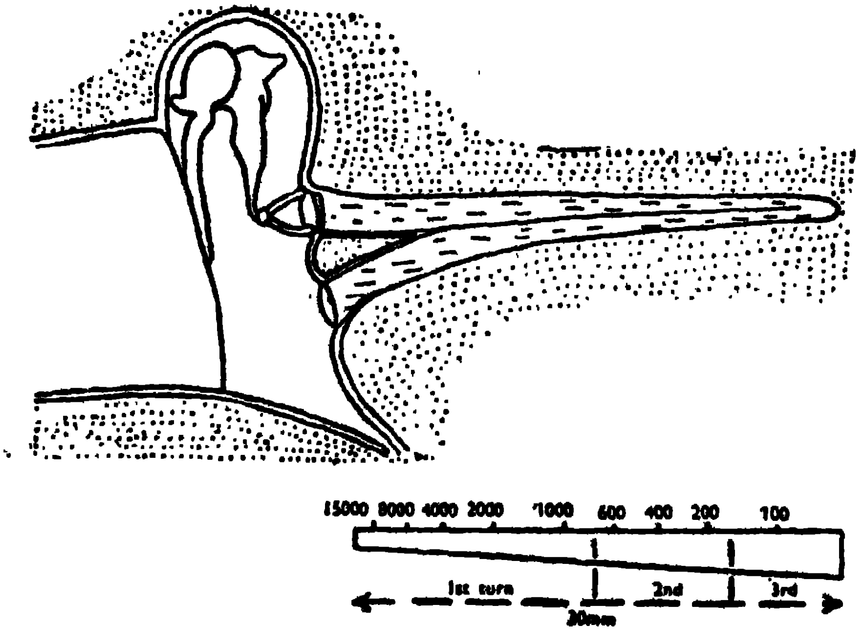


FIG. 44.—Diagrammatic section through ear with spiral tube unrolled (*after W. H. White*)

The lower diagram is a plan of the elastic membrane which divides this tube into two passages marked with the frequencies of the vibrations to which the different parts of this membrane respond

---

[1] From Jeans's *Science and Music.*

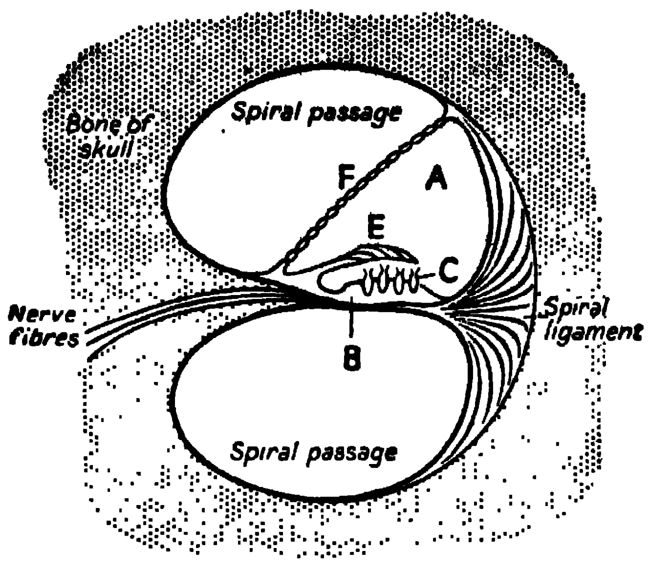


FIG. 45.—Diagrammatic section across organ of hearing.

This shows an enlarged cross-section of the spiral passages shown in Figs. 43 and 44.
A—third narrower duct lying between the two spiral passages in the cochlea.
B—elastic membrane supporting rods with sensitive hair-cells (C).
D—nerve fibres.
E—membrane forming 'shelf' overhanging the sensitive hair-cells.
F—membrane separating duct A from spiral passage.

Experiments on hearing

(i) Listen to the note of a whistle whose pitch can be gradually raised. Notice that when the pitch of the note gets very high it becomes more difficult to detect and finally it cannot be heard at all. Notice that some individuals can hear higher notes than others (e.g. some people cannot hear the very high-pitched squeak of a flying bat).

(ii) Place your flat hands, with their palms facing backwards, on either side of the head, just in front of the ears. Stand in front of a loudly-ticking clock and close your eyes. Where does the sound appear to come from? Your hands 'shade' the ear-passages from sound coming from the front, hence the sound-waves can only travel round the back and sides. Use your hands as extensions of your external ears and notice the increased loudness of sounds coming from in front of you.

Sense of balance and position

The inner ear contains the three *semicircular canals* which are concerned with the sense of position and balance of the body. Each of these three semicircular canals lies in a plane at right angles to the other two, and at one end of each canal there is a swelling that contains nerve-cells (see Fig. 46). The semicircular canals are filled with liquid, and when the head is moved in any direction this drags behind a little and affects the nerve-cells, which then send an impulse to the brain. In the brain this impulse gives rise to the sensation of *movement* in a particular direction.

It is clear that sensations of movement depend upon the movement of the liquid in the semicircular canals. But we can also sense the posture of the head even when this is not moving. This power is given by the *ampulla*, part of the organ of balance at the base of the canals. The cavity of this part is lined with nerve-cells, too, and contains tiny chalky particles that press on the lowermost nerve-cells. In the brain the impulses coming from these cells give rise to sensations of *position*. The organ of balance is helped in its work by other sense-organs. Thus our eyes tell us a great deal about our movement or position in relation to surrounding objects.

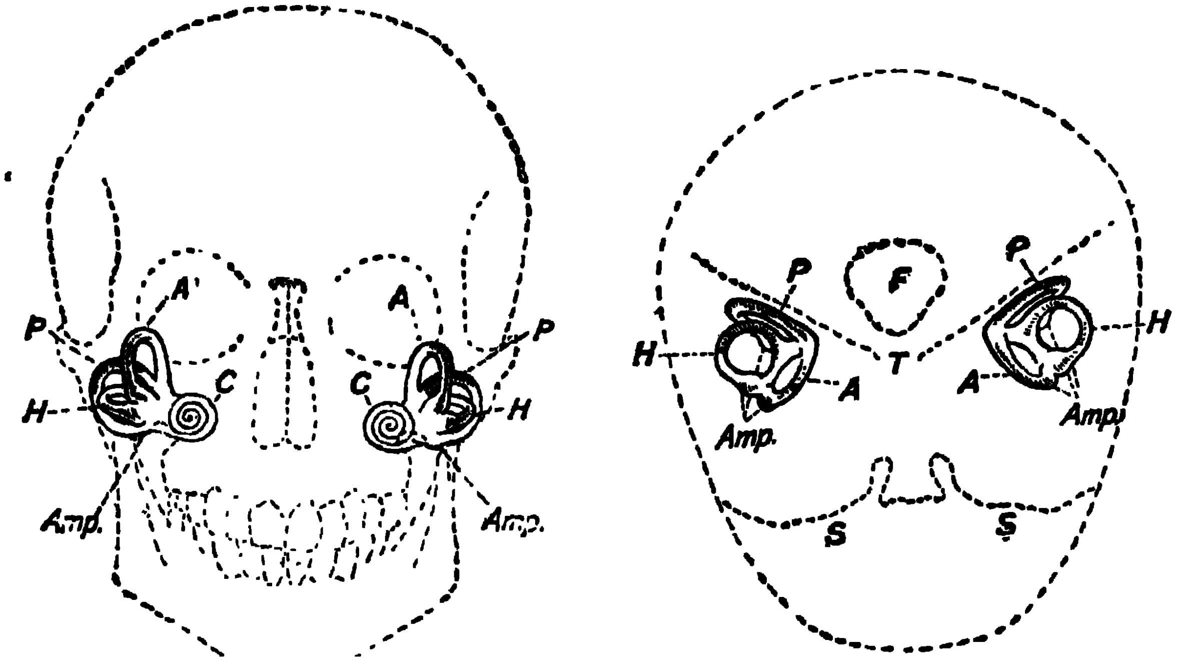


FIG. 46.—Diagram showing position of semicircular canals in head. I. View from front of head. II. View from back of head

A, H, P—semicircular canals. C—organ of hearing (cochlea). Amp.—ampulla

Internal sense-organs

There are other sense-organs, scattered throughout the body, which report to the brain what is going on in the voluntary muscles, tendons, joints, and in other parts of the body. For example, these internal sense-organs tell you when you are tired, when you are hungry or thirsty, or when your stomach is over-full. Similarly, it is not necessary to have your eyes open to know the movements and position of your limbs, because this information can be supplied by internal sense-organs.

Senses of taste and smell

The *organ of taste* is the *tongue* and the *organ of smell* is in the upper part of the *nose*. These two organs nearly always work together. In fact, it is usually difficult to decide whether a particular sensation is a taste or a smell. When one has a 'cold in the nose' one cannot smell, and at the same time food has very little taste. This is because most of our ideas of the 'taste' of foods also include their characteristic smell.

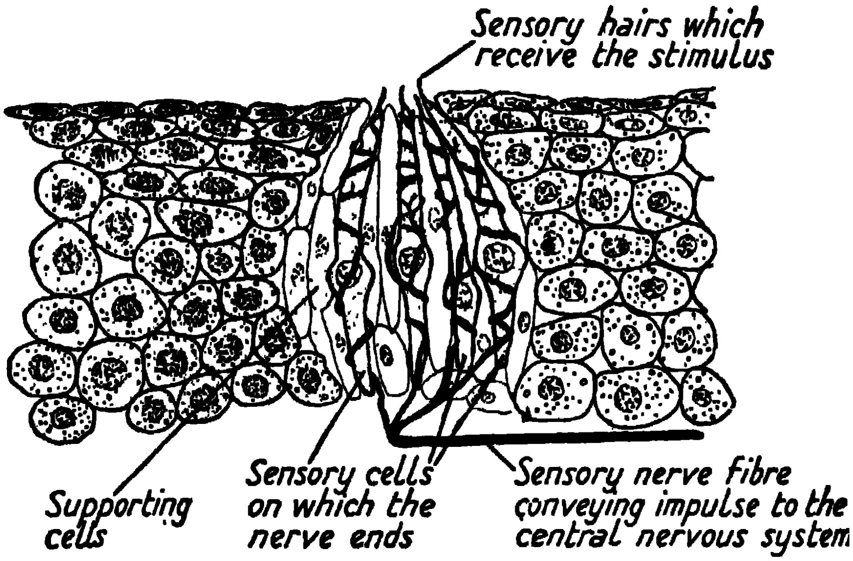

Sensory hairs which receive the stimulus
Supporting cells
Sensory cells on which the nerve ends
Sensory nerve fibre conveying impulse to the central nervous system

FIG. 47.—Section through taste-bud (much magnified)

We taste with special groups of sensitive nerve-cells called *taste-buds*, situated in tiny projections on the upper surface of the tongue and on other parts of the mouth-cavity. These taste buds are connected with the brain by nerve-fibres (see Fig. 47).

These *taste-buds*, which are only sensitive to substances that have *dissolved* in the saliva, are of four kinds, each corresponding to one of the four pure tastes—*sweet*, *sour*, *bitter*, and *salty*. Most everyday tastes are combinations of these fundamental tastes. The four kinds of taste-buds are not distributed evenly over the tongue. Thus we taste sweet things best with the tip of the tongue, where the 'sweet taste-buds' are most numerous, while bitter tastes affect mainly the back of the tongue. The sour and the salty taste-buds are mainly in the sides of the tongue: the sour taste-buds being most numerous about the middle of each side and the salty taste-buds being towards the tip of the tongue. We recognize the impulse received in the brain from the different taste-buds as a particular kind of taste.

We *smell* by means of special sensitive hair-cells situated on a square *smelling-patch* in the upper part of the nose-cavity (see Fig. 4). These cells are connected to the brain by nerve-fibres. As air passes through the nose, these sensitive cells are stimulated by any impurities that have a definite smell, and a stimulus is sent to the brain along the nerve-fibres. We recognize this stimulus as a particular smell. (See p. 257 for experiments on taste and smell.)

Feeling, touch, temperature and pain

We get much information about our surroundings through the sense-organs of *touch* situated just beneath the outer *skin* over most parts of the body-surface (see Fig. 20). When we touch anything, even with our eyes closed, we can say whether it is hot or cold, hard or soft, and whether it hurts or not.

This is because the skin has four kinds of sense-organs, each sensitive to one only of the four types of sensation: (i) *warmth*, (ii) *cold*, (iii) *pain*, and (iv) *touch*. Nerve-fibres carry stimuli from these sense-organs to the brain and to the spinal cord. (See p. 258 for experiments on the sense-organs of the skin.)

CHEMICAL CONTROL

Hormones

Internal co-ordination of different parts of the body is not always carried out by the nervous system. Co-ordination is also carried out by the circulation of chemical substances with the blood. These '*chemical messengers*' are called *hormones* and they are passed into the blood-stream by special *ductless glands* (see Fig. 48). For example, the pancreas does not pour out pancreatic juice continuously, but only when the small intestine contains food to be digested. Whenever food enters the small intestine from the stomach, cells in the wall of the small intestine produce a hormone that is passed into the blood-stream and carried round the body. When blood containing this hormone reaches the pancreas, it supplies a stimulus to that gland, which pours out pancreatic juice. The same hormone may also stimulate the flow of bile from the liver.

In female mammals, when a fertilized egg-cell begins to develop in the body, the pituitary gland produces another hormone that stimulates the growth of the milk-glands ready to supply milk for the young one after birth.

Another very important hormone is *adrenalin*, produced by the *adrenal bodies*, a pair of ductless glands lying just anterior to the kidneys. Under great excitement, e.g. anger or fear, the adrenal glands pass adrenaline into the blood-stream, and as the hormone is distributed to every part of the body it prepares almost every organ for special efforts. For example, the heart-beat becomes more rapid, the capillaries become wider, the liver converts more glycogen to glucose, the sweat-glands become more active and the activities of the food-canal are slowed down.

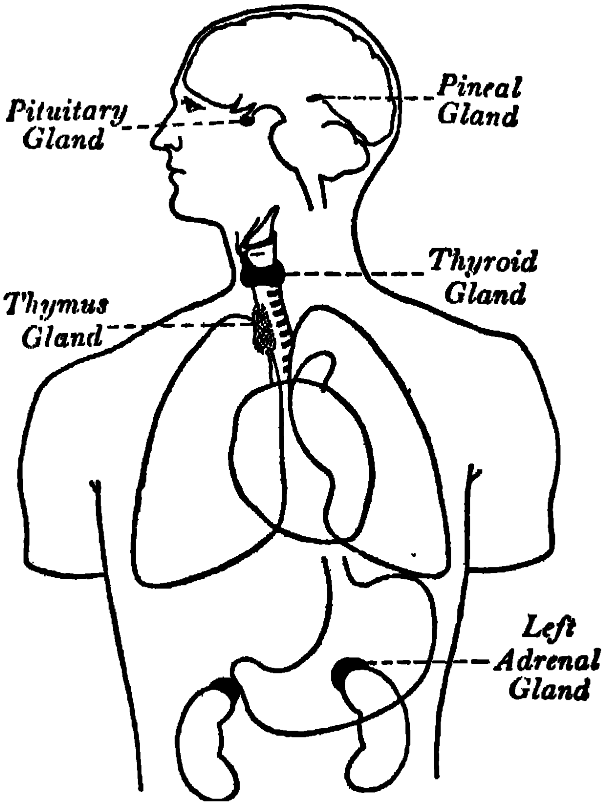


FIG. 48.—Position of the main ductless glands

The *thyroid gland*, in the neck, produces a hormone which regulates growth and development. A deficiency of this hormone slows down the heart-beat, blood circulation, and oxidation of glucose in the body tissues during respiration. Thyroid deficiency in young people restricts growth and bone development. Nervous activity is also reduced so that mental development becomes backward.

The *pituitary gland*, situated beneath the brain, produces another hormone which also controls growth. Most human 'giants' have unusually active pituitary glands, while a lack of this hormone produces 'dwarfs'.

You will notice that for rapid action the body uses nervous control and that when the action is slow and prolonged it is controlled chemically by hormones.

Hormones are rather like vitamins in that exceedingly small amounts produce very striking results. In fact, it has been suggested that 'vitamins may be regarded as hormones which the body cannot make for itself'.

Another type of chemical control

A different type of chemical control is carried out in animals by the waste products, carbon dioxide and urea, but these substances are not called hormones. For example, the diameter of the blood-capillaries varies according to the amount of carbon dioxide in the blood. When the body-muscles are resting, there is little carbon dioxide in the blood and the capillaries are very narrow. When the muscles are working, the blood receives more carbon dioxide and the capillaries widen, thus increasing the blood supply. At the same time, when this blood—containing more carbon dioxide—reaches the brain, nervous impulses are sent to the muscles between the ribs and to the diaphragm, and the breathing movements become deeper and more rapid.

Similarly, an increased amount of urea in the blood-stream stimulates the kidneys to greater activity in order to remove this excess of urea from the blood.

Instinct and intelligence

The behaviour of the lower animals is mainly guided by *instinct*; that is to say, their ways of behaving in various situations are *inherited*; they do not have to *learn* what to do. A spider does not have to learn how to spin its web, or a bird how to build its nest. In so far as it is inherited, and not learnt, instinctive behaviour is similar to reflex response, but it differs from the latter in some important respects. When a dog jumps on hearing a sudden loud noise, this is a reflex response to the stimulus of the sound. But if the dog hears the squeak of a rat, its response is not merely to the stimulus of the sound, but also to what the sound *means* to the dog. It is a signal meaning the presence of a rat, and the dog's activity is much more than the mere contraction of a group of muscles; it is directed towards finding and catching the rat. There is every reason to believe that, in the higher animals at any rate, instinctive behaviour is accompanied by consciousness, and that quite complicated mental processes may be involved. But the essential feature is that the lower animal knows what to do without having had to learn it.

The behaviour of the lower animals is mainly instinctive. When an animal is able to learn by experience, it is said to show *intelligence*. Experiments show that even such lowly animals as insects are not completely devoid of intelligence. Bees, for instance, can learn that honey is to be obtained from yellow containers but not from those of another colour. In all animals below mammals, intelligence probably plays a quite minor part in their activities. Dogs and cats, however, quickly learn a great many simple things, such as to come and be fed when called. Experiments have shown that they can learn such things as how to release themselves from a cage by pulling a string which passes over a pulley and is attached to the catch of the door.

Man is distinguished from the lower animals not only by his greater intelligence, but by his power of *reasoning*. The difference between intelligence and reason can be illustrated in this way. A monkey learns to open the door of a cage by pulling a string. It has discovered, in the first place by accident, that the door opens when the string is pulled. Being intelligent, it remembers this next time, and instead of trying to force its way out of the cage, looks for the string and pulls it. If the monkey were capable of reasoning it would not only discover that pulling the string opens the door, but would understand *why* pulling it does so. In other words, it would be able to form general ideas about mechanical devices and how they work. It is clear that an animal capable of *reasoning* can behave much more successfully in unaccustomed situations than can an animal which is merely intelligent. Instead of blundering in the chance of finding the right solution, it can think out how to modify the actions which it had found successful in different but somewhat similar situations, so as to suit the present situation. Experiments have demonstrated some power of reasoning in apes, and it appears to exist to a very slight extent in cats and dogs.

Man, however, clearly stands by himself among all other animals in the extent of his powers of reasoning. This has been greatly helped by his capacity for *speech*, for words enable us to formulate much more complicated ideas than we could without their use, just as a long multiplication sum would be impossible without symbols to express the different numbers. Moreover, *language* enables people to share their ideas and experiences and hand them down from one generation to another. This is one of the most important factors in *education*.

CHAPTER 6

THE SKELETON AND MOVEMENT

Movement is a characteristic of all living things, but it is more active and noticeable in animals than in plants. As a general rule, movements (apart from those of normal growth and continuous movements like heart-beat and breathing) are made in response to a *stimulus*. Living things are extraordinarily sensitive to changes in their environment. Usually a movement in response to such a change is such as to favour the individual making it—to allow it to survive. Most animals can move from place to place in search of food and to escape from their enemies. This movement is brought about in various ways in different types of animals, but all *vertebrate* animals have a bony framework, or *skeleton*, arranged on a characteristic general plan, consisting of a *main axis* (skull, backbone, ribs, breastbone) and two pairs of *limbs* (which may be either legs, or arms, or fins, or wings). We have already discussed (on p. 33) the general arrangement of the bones in the vertebrate skeleton, but we have still to discuss how movements of bones are brought about by muscles.

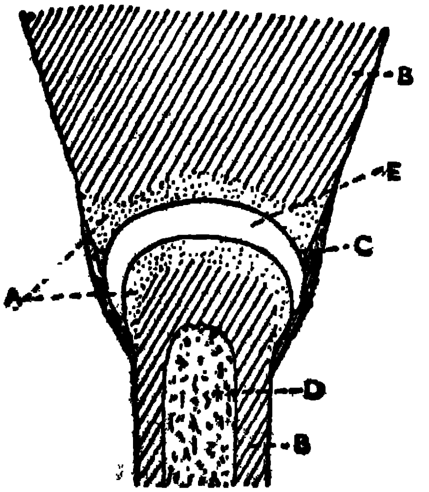


FIG. 49.—Diagram showing the structure of a joint

A—layer of gristle. B—bone. C—ligament. D—bone-marrow. E—sac of gristle enclosing slimy fluid

Where neighbouring bones, e.g. most of the skull bones and bones of the hip-girdle, do not move independently they often fuse together. However, many bones are jointed so as to be able to move freely; the movements are brought about by the contraction of the living muscles. In the human body there are 230 joints, large and small—as many as 25 are found in each leg.

The moving parts of the body are almost perfectly lubricated. Fig. 49 shows the way in which a joint is constructed. The bones do not touch but are bound together by strong fibrous tissue forming the 'capsule'; they are therefore not easily pulled out-of-joint or dislocated. In joints like the hip and the shoulder, the rubbing surfaces are smooth and rounded and the ends of the bones are covered with a thin layer of white *cartilage*. This is not only elastic, acting as a cushion, but it is also covered with a film of a slimy fluid which is the actual lubricant of the joint. This fluid fills the closed sac that separates the two layers of cartilage at the joint; it is formed from the membrane lining this closed sac as this gradually wears away and is replaced by new growth.

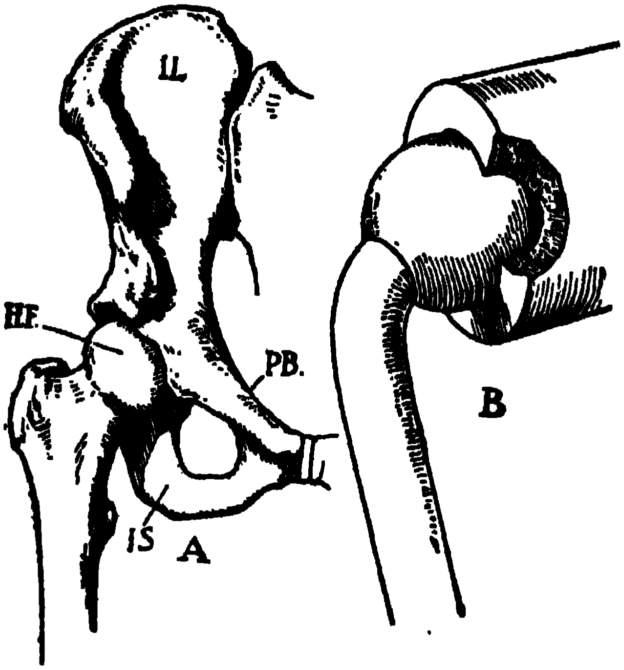


FIG. 50.—(*A*) The human hip-joint. (*B*) A simple ball-and-socket joint
HF—rounded head of thigh-bone. IL, PB, IS—fused bones of hip-girdle

The type of joint which allows the freest movement in all directions is the '*ball-and-socket*' type which joins the limbs to the limb-girdles (hip- and shoulder-joints) (see Fig. 50). '*Hinge-joints*' (e.g. those of the elbow, knee, jaw, and finger) allow movement in one plane only.

The muscles which move the bony levers of the body are, of course, living; they are made up of cells which have the special property of being able to contract. They can exert a pull but not a push. We find then, that every voluntary muscle is attached to at least two jointed bones, and nearly all these muscles are arranged in pairs. One muscle brings the jointed bones closer together when it contracts, the other pulls them back again to their original position. The nervous control of the muscular contraction is such that when one member of a pair contracts, the other relaxes.

MUSCLE ACTION

In all animals except the lowest, movement is brought about by *muscle-cells* whose special function is *contraction.* Large groups of these muscle-cells make up muscular tissue or *muscles.*

Muscle-tissue is of three main kinds: (*a*) *voluntary muscle,* (*b*) *involuntary muscle,* and (*c*) *heart-muscle.*

Voluntary muscles are sometimes called *skeletal muscles* because they are attached to bones and produce the movements of the skeleton. Such muscles are usually controlled by the will, hence the name 'voluntary muscle'. Under the microscope, voluntary muscle is seen to consist of fibres which show a cross-striped appearance, hence another name for voluntary muscle is *striped muscle* (see Fig. 51). Every voluntary muscle consists of a soft, thickened, central portion (shaped like a cigar) with a tendon at either end attaching the muscle to two bones. Muscle-cells contract in length as the result of a *stimulus* received from the central nervous system through a motor-nerve. It is important to realize that when a muscle shortens its length it becomes thicker, so that the *volume of the muscle remains the same.* When we say that 'a muscle contracts' we mean '*contracts in length*'; so it is better to say that '*a muscle shortens and thickens*'.

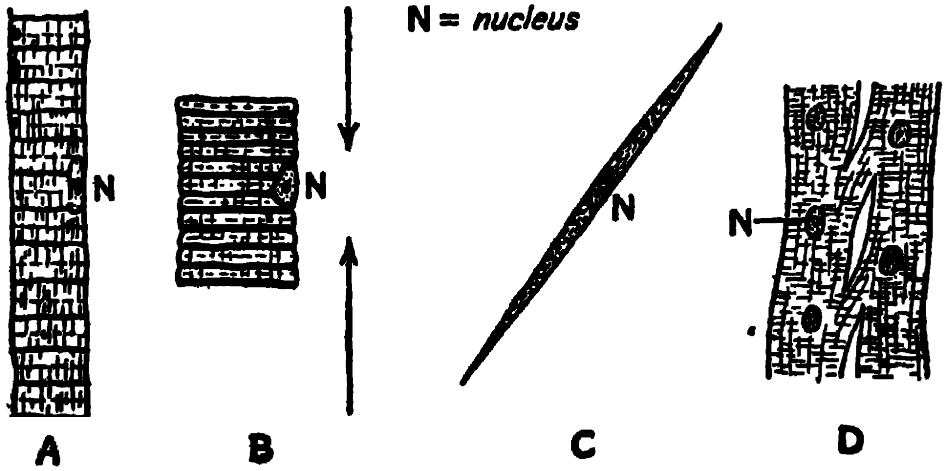


FIG. 51.—Muscle-fibres (magnified)

A—Part of voluntary (striped) muscle-fibre—relaxed (× 130). B—Same muscle-fibre contracted (× 130). C—Involuntary (smooth) muscle-fibre (× 700). D—Heart muscle-fibres (× 250).

The characteristic movements of voluntary muscle are *short, rapid contractions,* and this 'striped muscle' is always present in any part of an animal where rapid movement is required. Voluntary muscle, however, soon becomes *fatigued* (see p. 131).

Involuntary muscle is sometimes called *smooth muscle* or *unstriped muscle,* because it shows no cross-striped appearance under the microscope (see Fig. 51). Involuntary muscle is not attached to bones; but it is usually present in muscular sheets lining the internal organs, such as the food-canal and the blood-vessels, i.e. those parts of the body that are not under the control of the will. The characteristic movements of involuntary muscle are *slow, sustained contractions,* hence this 'unstriped muscle' is useless for producing rapid movements. For example, the unstriped, involuntary muscle of a frog's stomach may take 10 seconds to contract, as compared with 0·05 seconds for the contraction of the striped, voluntary leg-muscle of the same animal. Fatigue is slow in involuntary muscle.

The *heart-muscle* of vertebrates differs from voluntary and involuntary muscle in its microscopic structure and in being able to sustain fairly rapid movements *without any nervous stimulus* (see Fig. 51). Heart muscle does not become fatigued.

Muscle-cells are, of course, living. When they contract they *do work,* and we know that this requires *energy.* The muscle-cells, therefore, are energy transformers, converting *chemical energy* into *mechanical energy.* The source of this energy is the food substance that is broken down in the muscle-cell by the process of respiration. The actual chemical processes concerned have been found to be very complicated indeed and there is no need for us to know anything of the details at this stage.

TEETH

An important characteristic of mammals is their more or less permanent specialized teeth. The teeth of all mammals are built on the same ground-plan, although they may differ widely in size and shape according to the animal's feeding habits, e.g. the *carnivores* (or flesh-eating mammals, such as the dog, cat, lion, tiger) have teeth adapted mainly for tearing and cutting, while the teeth of *herbivores* (or plant-eating mammals like sheep and cattle) are adapted chiefly for chewing and grinding.

In every type of tooth, the part which is seen projecting into the mouth is called the *crown* of the tooth, while the part embedded in the jaw-bone is called the *root* (see Fig. 52). The region level with the *gum,* where the crown joins the root, is called the *neck* of the tooth. The greater part of a tooth consists of *dentine* (or ivory). Dentine, although very strong, is somewhat elastic, so that it supports sudden pressure without breaking. Dentine, however, is too soft to stand continuous wear, and the crown of the tooth is covered with a thin layer of a very hard substance called the *enamel.* Enamel is the hardest tissue in the body, and in fully-grown teeth it consists almost entirely of mineral (inorganic) material. Although the enamel is brittle, it is saved from breakage because it rests on the elastic dentine beneath. The enamel extends to the neck of the tooth. The dentine of the root is covered with a thin layer of bone-like *cement*, which helps to fix the tooth in its socket in the jaw. In the middle of the dentine is the *pulp-cavity*, containing a soft mass of blood-vessels and nerves, which enter through a tiny hole at the tip of the root (see Fig. 52).

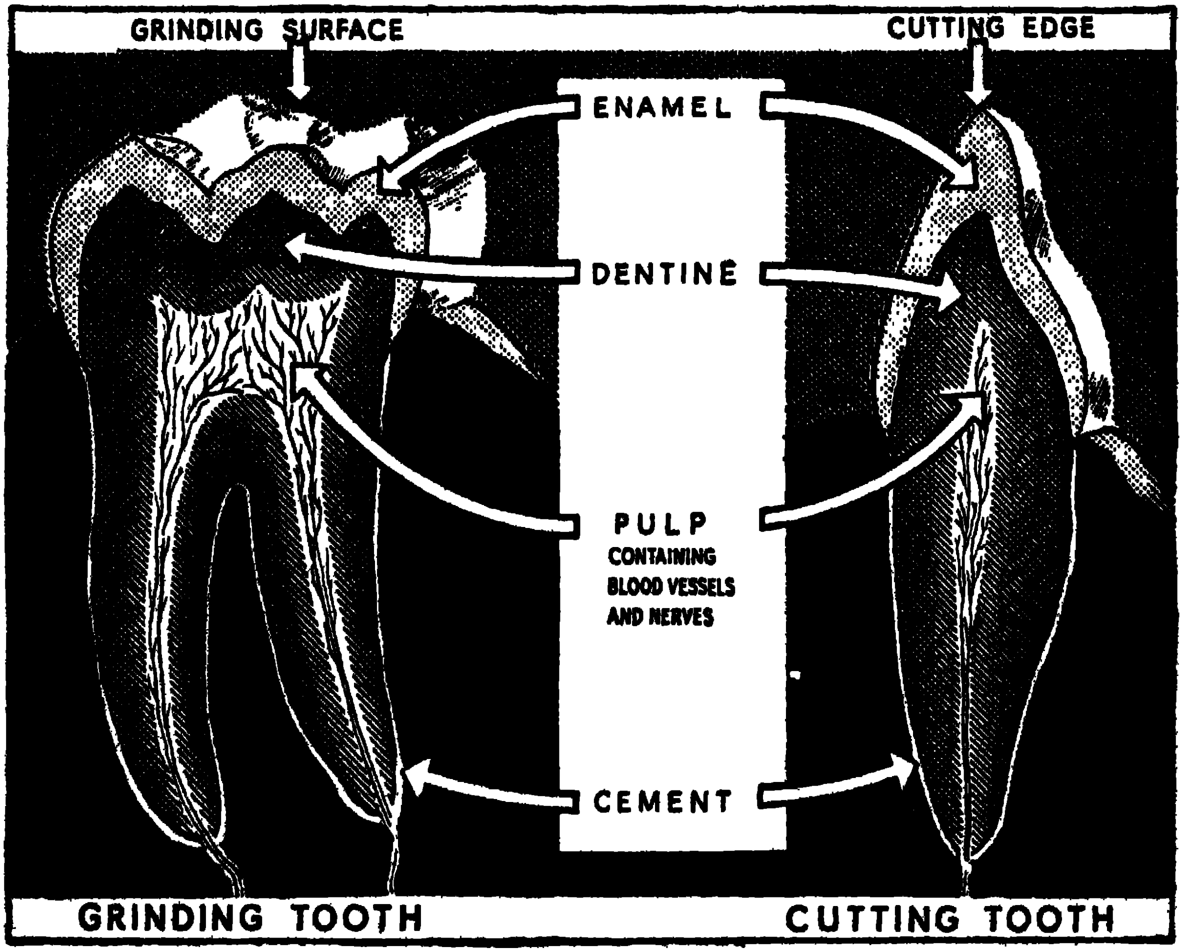


FIG. 52.—Tooth structure

Mammals have different kinds of teeth, each useful for different work. In Man, there are four kinds of teeth: (*a*) *Incisor teeth*—flattened, cutting teeth for biting and tearing food. These are the four front teeth in each jaw. (*b*) *Canine teeth*—more pointed and stronger than the incisors: two in each jaw, on either side of the incisors. These canine teeth are best developed in flesh-eating mammals, e.g. cats, dogs, and tigers, who use them to seize their living victims. (*c*) *Pre-molar teeth*—four small teeth in each jaw for breaking and crushing the food, placed in pairs behind each canine tooth. (*d*) *Molar teeth*—six large, 'double' teeth for grinding up the food and mixing it with saliva; three on either side of each jaw. There are no true molars in the temporary 'milk-teeth'; the so-called 'milk-molars' are pre-molars. (See Fig. 53.)

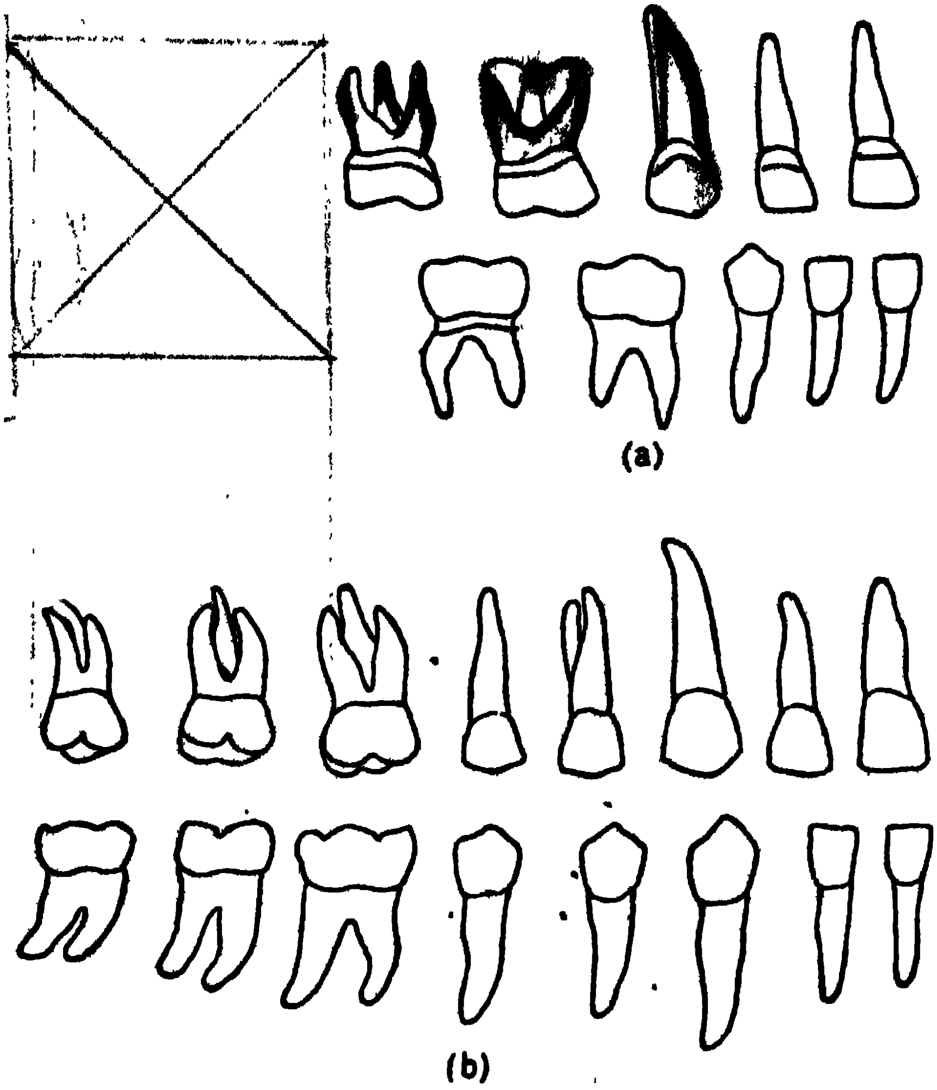


FIG. 53

(*a*) Human temporary teeth (*b*) Human permanent teeth

Man grows two sets of teeth—a *temporary set* during childhood and a *permanent set* when grown up. When a baby is about seven months old, the first front teeth appear. Other teeth appear gradually until by the time the child is about two years old, the temporary set is complete, consisting of four incisors, two canines and four pre-molars in each jaw. These twenty 'milk-teeth' serve the child until it is about six years old. During this time the jaws are growing longer, thus making room for the *permanent teeth*, which are gradually developing inside the jaws (see Fig. 54). At about six years of age, the first permanent molars appear, behind the temporary molars, and during the next few years the temporary teeth loosen and fall out, being replaced by the permanent teeth, until by the fifteenth year only the third molars (or 'wisdom teeth') have still to appear. The complete set of permanent teeth, therefore, consists of four incisors, two canines, four pre-molars, and six molars in each jaw, a total of thirty-two teeth.

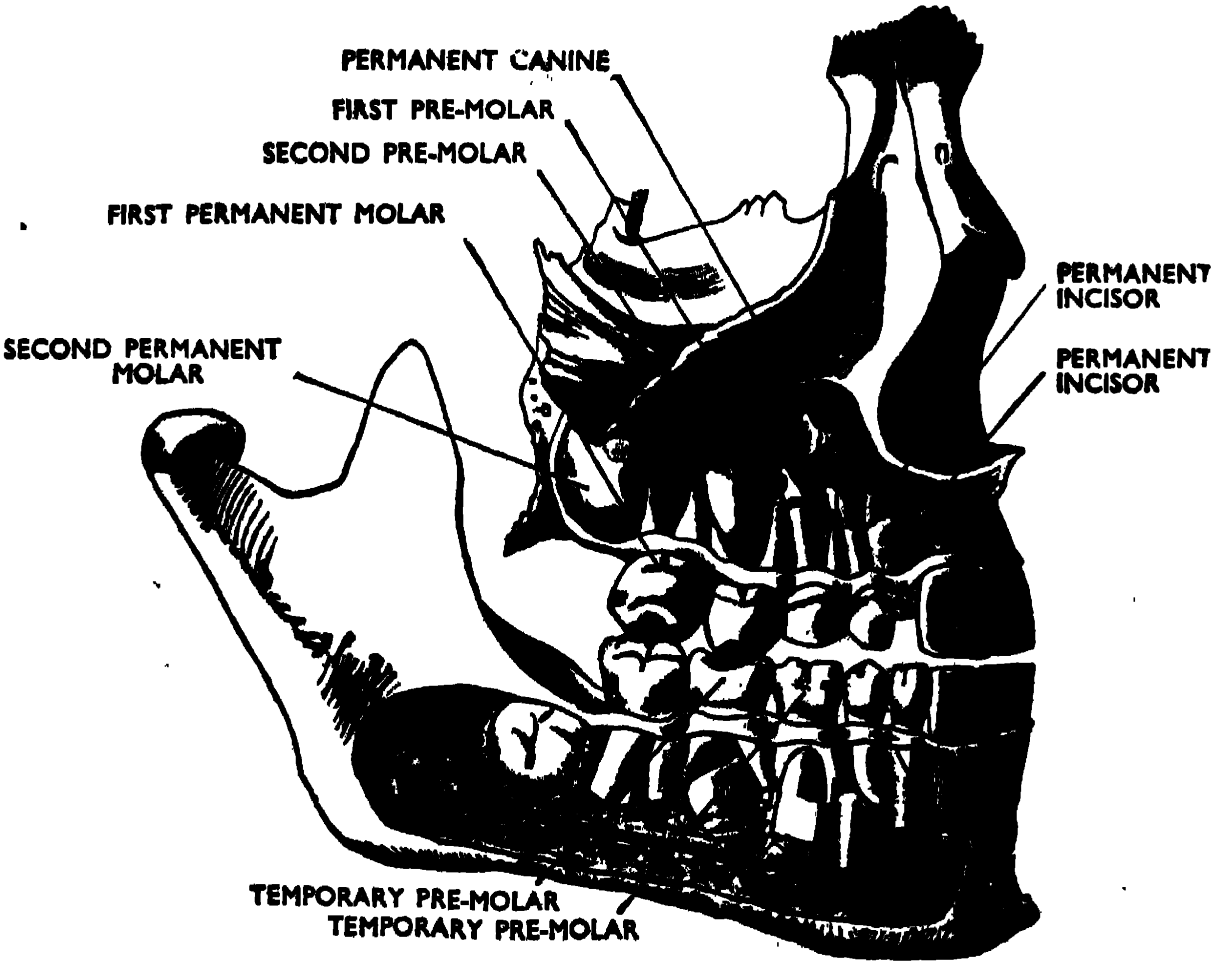


FIG. 54.—Upper and lower jaws of a six-year-old child

All the temporary teeth are present and the first permanent molars are coming through. The permanent teeth can be seen forming behind the temporary teeth

This is the most convenient point at which to consider diseases of the teeth and their prevention.

Diseases of the teeth

The causes of dental disease are best considered under two main headings:

(i) *local causes*, which affect the teeth directly, and (ii) *general causes*, which affect the body in general and the teeth in particular.

(i) *Local causes of dental decay.* Actual decay is caused by certain kinds of bacteria. Our mouths, and the food we eat, contain large numbers of bacteria, of many different kinds. Most of these bacteria are harmless, but some of them feed on food particles left sticking to the teeth, and as they feed they produce organic acids which dissolve the enamel, forming tiny holes. These holes get bigger and deeper, eating through the enamel and extending into the dentine. The softer dentine decays still more rapidly, until the pulp is attacked and then there is severe toothache owing to exposure of the nerves. Once bacteria enter the pulp, they can travel down through the pulp cavity and form an *abscess* round the root of the tooth (see Fig. 55). Such an abscess is a mass of bacteria, and the poisonous substances it produces may enter the blood-stream and be carried to all parts of the body, causing other disturbances. An abscess may cause a gumboil or a swelling of the face, which drives the sufferer to a dentist. Sometimes, however, an abscess causes no local pain since its poisonous products are being carried away to other parts of the body by the blood-stream, causing serious disturbances which seem to have nothing to do with the teeth until an X-ray picture of the jaw shows the real cause.

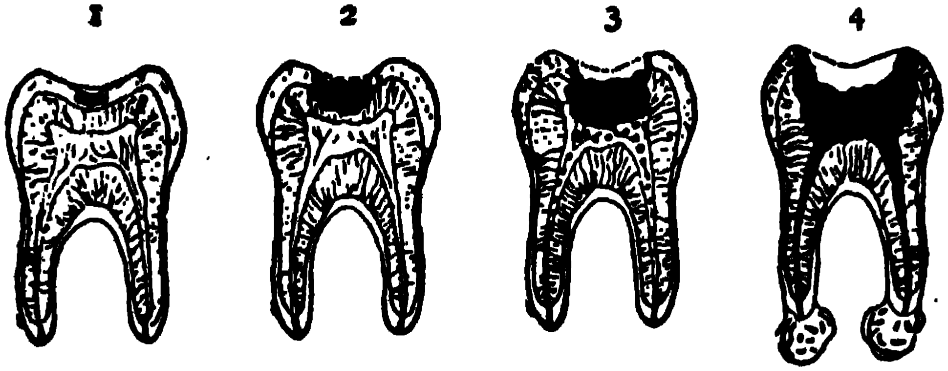


FIG. 55.—Four stages of dental decay

1—enamel begins to decay. 2—dentine also begins to decay. (A dentist can save this tooth.) 3—pulp begins to decay. 4—pulp completely decayed; abscesses formed

Another local cause of dental decay is badly-shaped, unevenly-spaced teeth. Such teeth are difficult to keep clean, since it is not easy to remove particles of food from the awkward spaces between the teeth.

(ii) *General causes of dental decay.* If dental decay were due only to such local causes, then clean, well-shaped, and well-spaced teeth should never decay. (In fact, it was formerly believed that 'a clean tooth never decays'.)

Unfortunately, such teeth often do decay, hence there must be other causes of decay besides those which affect the mouth and teeth directly.

Many teeth which appear quite normal on the surface are badly formed inside, and such teeth very often decay. In some cases, a serious illness or a long period of ill-health during childhood results in a small area of badly-formed enamel which is easily dissolved by acids.

Proper diet has a great influence on the formation of good teeth, and we have seen (on p. 68) that although a diet may contain enough calcium and phosphorus compounds, the body cannot make use of these compounds to grow strong, well-formed teeth unless *vitamin D* is also present in the diet.

Prevention of dental disease

In order to prevent dental disease, four main conditions are necessary: (i) *The teeth must be well formed and strong*. (ii) *They must be well arranged in the mouth.* (iii) *They must be properly used.* (iv) *They must be kept clean.*

(i) We have seen that in the formation of good, strong teeth it is necessary to have a suitable diet containing enough *calcium* and *phosphorus* compounds, together with *vitamin D*. Such a diet will include milk, eggs, butter, cheese, animal fat, fresh fruit and green vegetables.

(ii) If the teeth are regular in shape and well spaced in the mouth, they are less likely to decay and will chew the food better. Young children should not be given 'comforters' to suck, and should not be allowed to suck their fingers, as these practices often displace the growing teeth. In some children, the temporary teeth remain too long in the jaw and hinder the normal growth of the permanent teeth. In such cases, the temporary tooth which is in the way should be pulled out to allow the permanent tooth to move into its proper position. (See Fig. 54.)

(iii) One of the main causes of the dental decay so widespread in 'civilized' communities is the *lack of tough food requiring vigorous chewing*. The teeth and jaws are adapted for biting, crushing, and grinding food. 'Uncivilized' peoples, eating coarse, tough, uncooked food, often avoid the dental decay which is so common among 'civilized' peoples. If the jaws are not properly used in childhood they remain small and narrow so that there is not enough room for the teeth. Active use of the jaws during chewing stimulates the blood supply to the teeth and the flow and movement of saliva. Apart from its digestive action, saliva cleans the teeth by washing away food particles. The alkaline saliva also neutralizes the harmful acids formed by the bacteria which cause decay. Hard chewing of tough, fibrous foodstuffs also helps to clean the teeth by removing the sticky film left by soft starchy and sugary foods.

Unfortunately, under modern conditions, with diets of soft, over-refined, cooked food, very little chewing is required. Hence the diet must always include hard and fibrous food materials to encourage the healthy habit of chewing. Substances like hard biscuits, bread-crusts, fresh fruits, and raw green vegetables are all of value from this point of view. Chewing sugar-cane is particularly good for the teeth.

(iv) We have seen that with a proper diet and vigorous chewing, no artificial cleansing of the teeth would be necessary, but under conditions of 'civilized' life, artificial methods have to be used. A tooth-brush or fibrous stick is generally used for the purpose, brushing *all* the surfaces of *all* the teeth with up-and-down and roundabout movements rather than backwards and forwards in a horizontal direction. As far as possible brushing should be *from* the gums so as to keep the gum pressed tightly around the neck of each tooth. A tooth-paste or powder helps the cleansing effect. In place of expensive commercial tooth-pastes and powders, a strong solution of common salt, or of baking soda (sodium *bi*-carbonate), or a mixture of the two, will help the tooth-brush to do its work. The teeth should always be cleaned before retiring for the night, after taking the last food for the day, so that the harmful bacteria may not become active during the hours of sleep. If possible, the teeth should be cleaned after each meal; the mouth, at least, should be thoroughly rinsed out with clean water.

Tartar is the name given to a hard deposit that often forms on teeth (particularly behind the lower incisors in adults). It consists of a mixture of calcium phosphate and calcium carbonate bound together by organic matter. Tartar should be removed periodically (by a dentist), because it may force back the gum and expose the dentine around the neck of a tooth below the enamel.

Dental inspection

Nearly all the permanent teeth develop during school-days, and the main object of school dental inspection is to ensure that there shall be a set of strong, healthy teeth in the adult. Regular inspection by a qualified dentist makes it possible to discover the early stages of decay and then save valuable teeth by discovering and filling tiny cavities. Dental decay is commonest during early life, and the process is more rapid in the young than in adults.

CHAPTER 7

HYGIENE OF THE SKELETAL, MUSCULAR, AND NERVOUS SYSTEMS

The skeleton forms the framework of the body and gives it its definite shape, besides protecting the more delicate organs. At about twenty-five years of age, the bones stop growing and their shape is fixed.

A baby's skeleton consists largely of soft cartilage, which gradually changes into hard bone during growth. For this reason, a child's skeleton is fairly soft and flexible, and its shape can be changed. In childhood, therefore, it is very important to see that the skeleton is properly shaped before growth stops and the bones harden. If children always stand and sit squarely, in an upright position, their skeleton will be well shaped. Young children should not be allowed to carry heavy loads. If an uncooked chicken bone is soaked in vinegar or some other weak acid for a few days, although it will still *look* the same it has become so flexible that it can be tied in a knot. This is because the acid had dissolved out the mineral matter (mainly calcium phosphate and carbonate) leaving only the organic framework. If a similar bone is burnt, however, it becomes brittle because the organic material has burned away. The bones of young children are richer in organic matter and therefore much less brittle than those of old people (whose bones contain more mineral matter). Children's bones, therefore, break less readily than those of adults and their fractures mend more easily. In fact, when the bones of children do break, they usually remain connected at one side of the fracture, just as a green stick does not break clean across (as does a dead dry stick). Hence the term 'green-stick' fracture is applied to such cases.

Good posture during childhood helps to provide an efficient, well-shaped skeleton in the adult. Besides this, a properly developed skeleton allows plenty of room for the free action of the heart, lungs, and other organs of the body. Physical exercises and suitable games provide the best means for the proper development of the skeleton and also for correcting such defects as stooping, round shoulders, or holding one shoulder higher than the other (see Figs. 56 and 57).

Since the hard, mineral part of bone is mainly calcium phosphate, it is essential that the diet of a growing child should contain sufficient *calcium* and *phosphorus* compounds in the right proportions. But in order to absorb these calcium and phosphorus compounds, the body must have sufficient *vitamin D*. Vitamin D, we have seen, is present along with vitamin A in milk, butter, eggs, and in fresh, green, leafy vegetables. It is also formed from *ergosterol* in the skin when exposed to sunlight (hence there need be no lack of vitamin D in tropical countries), and any child eating sufficient of these foods and getting sufficient sunlight and out-of-doors exercise, together with proper rest and sleep, is supplying the needs of the young skeleton. In some cases it may be desirable to increase the intake of vitamin D by giving the child fish-liver oil.

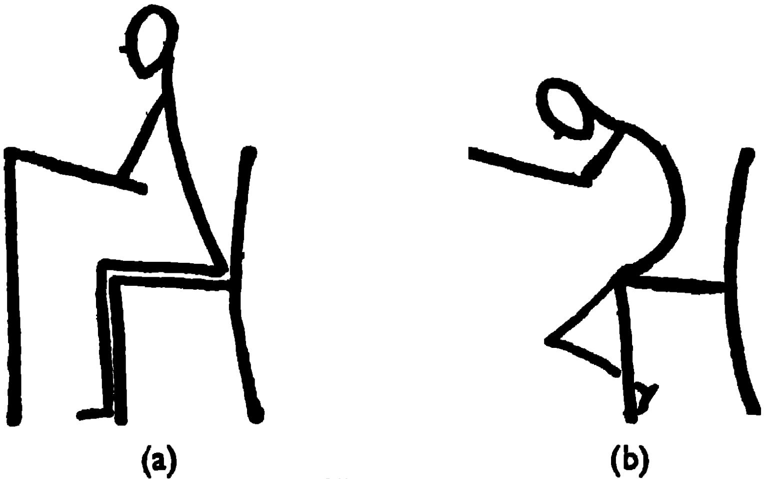


FIG. 56

(*a*) Good writing position. (*b*) Bad writing position

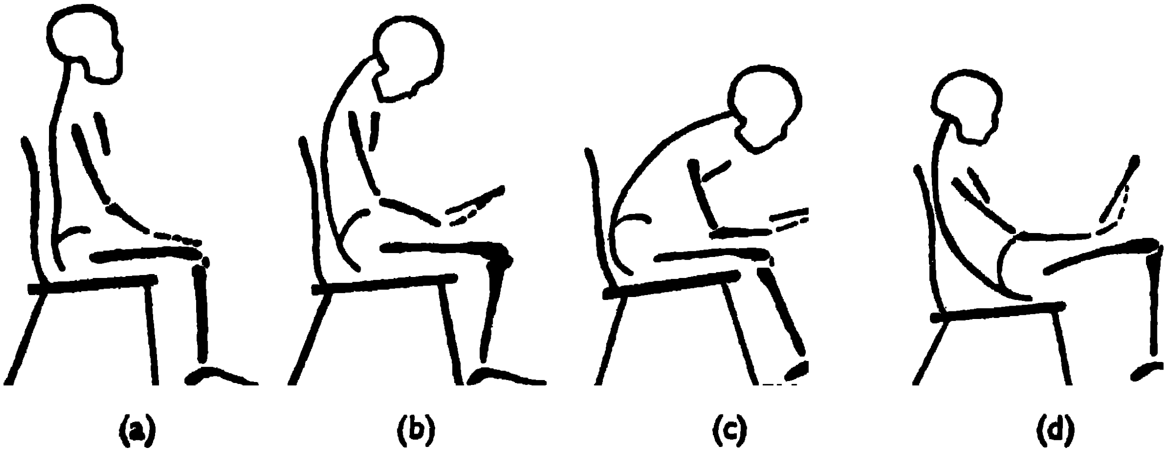


FIG. 57. Sitting postures

(*a*) Good. (*b*) (*c*) (*d*) Bad

BONE INJURIES—FRACTURES

Everyone should know a few guiding principles about how to deal with broken bones. The chief principle is, 'Do not make things worse by moving the injured person unnecessarily.' If possible, let him remain where he is until the doctor or the ambulance comes. If the injured person *must* be moved before proper medical attention arrives, *the injured part must first be protected from further injury* by bandaging the injured part to a splint or similar firm support. With a *compound fracture* (i.e. when a broken bone is sticking out through the skin) *do not try to push back the bone beneath the flesh*. This must be done only by a doctor (after thoroughly cleansing bone and wound).

You should learn the proper use of slings, bandages, and splints in dealing with broken bones by attending a *practical* First Aid course conducted by a doctor or qualified expert.

VALUE OF MUSCULAR EXERCISE

We have seen that it is by means of the muscles that the various parts of the body move. If the muscles are to do this efficiently they must be strong and healthy. To build up the muscles of a growing child, a sufficient supply of suitable food is required. After absorption, the food material must be carried to the muscles by the blood. *Exercise* increases the flow of blood to the muscles. Without exercise the muscles do not develop properly, but remain soft and weak. People that do heavy muscular work for several hours every day, using the large muscles of the body, get all the muscular exercise they require; but people doing indoor work, often sitting down for hours at a time, are not using their muscles sufficiently. It is most important that every normal person should exercise the muscles actively, so as to produce (*a*) *free sweating*, (*b*) *full action of the lungs*, (*c*) *increased action of the heart*, and (*d*) *more rapid circulation of the blood*.

Exercise not only makes the muscles strong and healthy, it also does good to every organ of the body. We may summarize the effect on the various body-systems as follows: (i) *The blood system*—Exercise makes the heart beat quicker and the circulation more rapid, resulting in a better blood-supply to the tissues, carrying food material and oxygen and removing waste material. (ii) *The skin*—Exercise causes the sweat-glands to become very active, giving out water and waste substances from the skin. (iii) *The lungs*—During exercise, the lungs become more active, breathing is deeper and the air in the lungs is changed more often, so that more oxygen is taken in and more carbon dioxide and water-vapour given out. (iv) *The food-canal*—Exercise encourages regular action of the intestines and prevents constipation. (v) *The nervous system*—Exercise stimulates the nervous system, refreshing the brain owing to the increased circulation of the blood.

Outdoor games of skill, e.g. cricket, football, hockey, tennis, &c., provide exercise for both the muscles and the brain, since it is only when the nervous system is working perfectly that the muscles can be properly controlled. Active muscular exercise is particularly important for those who spend several hours a day in 'brain work'. Merely watching games is useless. The healthy youngster who gets plenty of suitable food and exercise will usually develop a good posture.

FATIGUE—REST—SLEEP

Too much exercise causes *fatigue*, both muscular and nervous. We feel tired not because the carbohydrate in the muscles has been oxidized and used up, but because the chemical products of the oxidation are not being removed fast enough by the blood. Fatigue, therefore, is not like the loss of power of a petrol-engine through a stoppage in the fuel supply, but rather like the loss of power in a machine whose moving parts are stiff with dirt. The cure for fatigue is *rest*.

During rest, the harmful products of the activity of muscle- and nerve-cells are removed by the blood while the tissues are repaired and made ready for further activity. Whenever possible, it is better to *lie down* to rest, so as to relieve the heart of the work of pumping blood against gravity. The best form of rest is *sound sleep*. During sleep we become unconscious of outside happenings, and body and brain get a complete rest. The muscles relax, the heart beats more slowly, and the breathing becomes shallow. Most people in the tropics need eight hours of unbroken sleep every night. *Growing children should never have less than this.*

HYGIENE OF THE NERVOUS SYSTEM

The nervous system is so closely connected with the muscular system that what has been said about the hygiene of the muscular system applies also to the nervous system. *Fatigue* affects the nerves even more than the muscles. The most tiring work never completely fatigues the muscles.

Long before this stage is reached the nervous system has become so fatigued that it cannot supply the necessary impulses to keep the muscles moving. *Rest* and *sleep*, therefore, have even more important effects on the nervous system than on the muscles.

The brain, too, needs 'exercise'. A man who does the same work every day in the same way needs a change during his spare time. This is one of the main reasons for the value of a spare-time *hobby* which exercises the brain in a different way. Hence the 'brain-worker' should have a hobby which needs some muscular effort, while the hand-worker should have a hobby which needs some effort of the brain.

HYGIENE OF THE SENSE-ORGANS

There are five main ways in which we get information about the outside world—by our senses of *sight*, *hearing*, *taste*, *smell*, and *feeling* (touch, temperature, and pain); and it is important to keep all the *sense-organs* working efficiently if we are to respond properly to outside stimuli.

Hygiene of the eyes

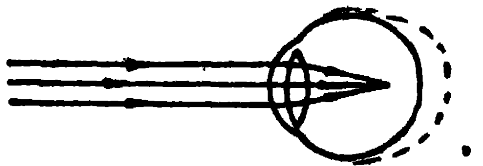
The eye is Man's most important sense-organ, and poor eye-sight is a great handicap. Common defects are *short-sight* (or near-sightedness) and *long-sight* (or far-sightedness). A near-sighted (or short-sighted) person can only see objects clearly when they are near to him, and he cannot see clearly objects beyond a certain distance. This is because the transparent covering in front of the eyeball is too much curved or because the eyeball is too long from front to back, so that parallel rays from a distant object are brought to a focus *in front of the retina*. In other words, the converging effect is too great, as shown in Fig. 58(*a*). This can be corrected by placing a suitable concave (or diverging) lens in front of the eye, so that the image of a distant object is formed on the retina (Fig. 58(*b*)). *A short-sighted person, therefore, needs eye-glasses* (or *spectacles*) *with concave lenses*. A near-sighted child can read easily and often does well in class, but out of class he cannot see clearly enough to play games well. So he tries to avoid games and becomes a 'book-worm'. By wearing suitable spectacles, the handicap of short-sight can be overcome.

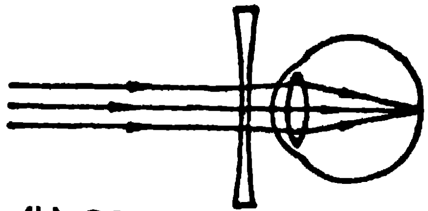
A *long-sighted* person can see distant objects clearly but not near objects. This is because the transparent covering in front of the eyeball is not sufficiently curved or because the eyeball is too short from front to back, so that rays from a near object are brought to a focus *behind the retina*.

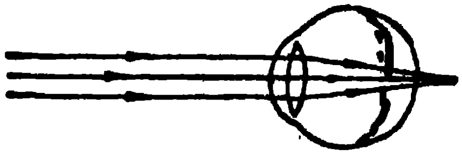
In other words, the rays are not converged sufficiently, as shown in Fig. 58(*c*).

This fault can be corrected by placing a suitable *convex* (or converging) lens in front of the eye so that the image of a near object is formed on the retina (see Fig. 58(*d*)). *A long-sighted person, therefore, needs eye-glasses with convex lenses.*

A third kind of eye-trouble often develops as people get older, when the eye-lens gets harder and less elastic, and the ring of muscle is unable to squeeze it sufficiently to make it more convex when looking at near objects. Older people, therefore, often need glasses with *convex* lenses for reading; in fact they often require two pairs of glasses, one for reading and one for viewing distant objects. Such people often find it convenient to have both types of lenses combined in a single pair of *bi-focal spectacles*, with 'distant' lenses above and 'reading' lenses below. This arrangement makes it unnecessary to have two separate pairs of glasses and to change from one pair to the other at frequent intervals.


(a) SHORT-SIGHTED EYE


(b) CORRECTION OF SHORT-SIGHT


(c) LONG-SIGHTED EYE

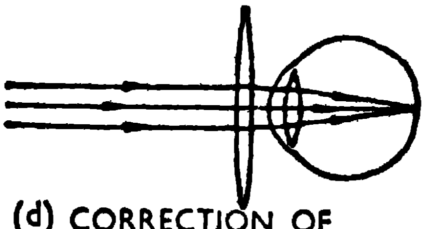

(d) CORRECTION OF LONG-SIGHT

FIG. 58.—Faults of eyesight and their correction

Another very common eye-defect, often overlooked, is *astigmatism*. This is caused by irregular curvature of the eye-lens or of the transparent window in front of the eye, which are often slightly spoon-shaped and not spherical. This defect is easily corrected by wearing suitable glasses. Eye-defects should be treated at as early a stage as possible, or the eyes may be permanently damaged. Early treatment, e.g. the wearing of suitable glasses, will often remedy the defect. Headaches and nervous trouble are often caused by slight defects of eyesight, owing to the continuous unconscious effort to correct the defect. The choice and fitting of suitable glasses, however, call for skilled knowledge and should be directed by a medical eye-specialist wherever possible. Eye trouble is sometimes only a sign of some other disturbance in another part of the body which will not be cured by wearing glasses. A doctor can find out and treat the *cause* of the trouble. Do not put off wearing glasses if an eye-specialist says you need them. Wearing suitable glasses will help to prevent your eyes getting worse and will also improve your general efficiency. Reading and writing should always be done in a good light, with no shadows on the page and no direct reflection from the shiny paper. In reading and writing, the book or paper should be square to the front and not nearer than twelve inches from the eyes.

Most of the diseases that affect the eyelids and the front of the eyeball are caused by infected dust and dirt entering the eyes. The eyes must never be rubbed with dirty hands or with a dirty towel. At the first sign of any redness or soreness about the eyes, they should be bathed with a weak antiseptic, e.g. a solution of boric acid. If this treatment does not put things right, a doctor should be consulted.

Eye diseases are very common in tropical countries (particularly among people whose diet is lacking in vitamin A). One of the commonest and most serious of these is *trachoma,* which is responsible for many cases of partial or total blindness. It appears to be caused by a virus which is present in the discharge from diseased eyes and is carried from the sick to the healthy by fingers, flies, towels, handkerchiefs, &c. As trachoma is very difficult to cure, prevention is most important, and anyone suffering from sore eyes should be isolated as far as possible, and should not share towels, soap, wash-basins, or any similar articles with other people.

Although the movement of the eyelids usually stops solid particles from entering the eye, it sometimes happens that bits of hard material get under the eyelid and become very painful. If hard particles get in the eye, it is very important not to rub the eye. Get a friend to remove the object on the corner of a clean handkerchief, or do it yourself with the aid of a mirror. If the object is only small, it will usually find its way to the inner corner of the eye where it can be easily removed. If there is the slightest difficulty in removing something from the eye, go to a doctor or a dispensary.

The front of the eyeball is kept always wet with 'tears', and when you get anything in your eye more 'tears' are produced to wash away the obstruction. Tears form one of the strongest natural antiseptics (see p. 206) and provide your best means of protection against eye-infections.

Hygiene of the ears

The middle ear and the inner ear are completely enclosed in thick bone and are thus well protected. On the other hand, if anything goes wrong inside the internal ear treatment is very difficult. The outer ear is merely a tube leading to the ear-drum. Wax is formed on the lining of this tube, and this sticky material traps dust and keeps out insects. The commonest trouble in this part of the ear is the accumulation of too much wax. Some people produce so much wax that it blocks up the tube and makes them deaf. A small excess of wax can usually be removed by twisting up the corner of a soft handkerchief and turning it *gently* round in the ear. No solid article should ever be put into the outer ear. Larger deposits of wax, and any foreign bodies should be removed by a doctor, by careful syringing so as to avoid harming the delicate ear-drum.

As far as possible, water should not be allowed to enter the outer ear, but if it does the tube should be thoroughly dried afterwards. This is particularly important in tropical countries where the spores of fungus diseases may find their way into the ear along with water. Never dry your ears with a dirty towel.

The middle ear is connected with the throat by a narrow tube (the 'Eustachian tube'), about 1½ inches long, which serves to equalize the pressure in the middle and the outer ear. This tube is sometimes a source of danger, since germs from the throat may find their way into the middle ear. Ear-ache is the danger-signal of such infection, and a doctor should be consulted at once. Any pus which forms in the middle ear cannot drain away naturally, and if the infection is neglected, there may be very serious results. The ear-drum itself may be burst or the chain of small bones may be disturbed, causing deafness. Worse still, the thick but spongy bone enclosing the middle ear may also become infected and in this way infection may spread to the brain with fatal results. (As a famous surgeon once said, 'It is safer to carry dynamite in your pocket than pus in your middle ear.') Remember, therefore, that *ear-ache (especially in a child) is a sign of danger*, and consult a doctor at once.

Hygiene of the organs of taste, smell, and touch

The tongue is the organ of taste, and needs very little attention to keep in good working order. The sense of taste may be damaged, however, by eating too highly flavoured food (e.g. 'hot curries') or by excessive smoking.

The upper part of the nose-cavity contains the organ of smell. When this cavity is blocked with sticky fluid (mucus) owing to a 'cold in the nose', the sensitive nerve-endings are covered and the sense of smell is lost. Under such conditions, be careful how you 'blow your nose', pressing one nostril at a time and keeping the lips apart. The common method of first filling the lungs with air, holding both nostrils firmly, closing the mouth tightly and then blowing hard through the nose often forces infected mucus up the Eustachian tubes and also into the bony cavities (*sinuses*) that open out from the nasal cavity (see Fig. 4).

The organs of feeling in the skin—sensitive to heat, cold, touch, and pain—are kept working efficiently if the skin is kept clean and healthy.

CHAPTER 8

HYGIENE OF THE RESPIRATORY SYSTEM

In Chapter One we saw that, in breathing, the blood is brought very close to the air in the lungs. It gives up carbon dioxide (and some water), which it brings from all parts of the body, and takes up oxygen, which it carries round the body to every cell. We have seen, too, how by lifting the ribs and flattening out the diaphragm the volume of the chest-cavity is increased and the pressure of the air in the lungs is lessened, so that the greater atmospheric pressure outside forces air into the lungs.

No one has to be taught to breathe, but it is sometimes necessary to learn how to keep the lungs in good working order, because under civilized conditions people who do no hard muscular work often use only a part of their lungs. If the lungs are only partly used day after day, they may become weakened and unable to work to their original full capacity. It is most important, therefore, that for a few minutes at least, every day, the lungs should be fully exercised. This can be done by daily deep breathing-exercises, working the ribs and diaphragm to their full extent, or better still, by active exercise, e.g. running, which makes one 'out of breath' and produces rapid, deep breathing. In this way regular and suitable exercise will enlarge the lungs and make them capable of harder work. It is clear that tight clothes and belts will discourage proper breathing movements. A bent posture of the body when standing up or sitting down also restricts the movement of the ribs and diaphragm and so hinders proper breathing. Measurement of 'chest expansion' shows whether the lungs are in good working order or not. This should be about three inches.

In Chapter One it was shown that the nose is specially adapted for cleaning, moistening, and warming the air as it is breathed in, and that the mouth has these safeguards less well developed. Hence by day and by night all ordinary breathing should be through the nose.

The action of the nose in filtering out dust from the air during breathing is very important. Air always contains varying amounts of dust (living and non-living). The 'non-living dust' consists of tiny particles of earth and stone, bits of animal hair and dead skin, bits of fibres worn away from clothing, bits of plant parts, and particles of soot from the smoke of fires. Unless this dust is filtered out from the air as it is breathed in, there will be formed a coating of dirt lining the branching air-tubes and tiny air-sacs in the lungs, and the exchange of gases between the blood and the air will be hindered. The 'living dust' often contains some disease organisms, and in correct breathing these are usually trapped as they enter the nose.

Diseases which can be carried by air and enter the body by way of the respiratory system are *sore throat*, the *common cold*, *diphtheria*, *influenza*, *whooping-cough*, *measles*, *smallpox* and *chicken-pox*, and *consumption* (i.e. tuberculosis of the lungs).

THE IMPORTANCE OF FRESH, CLEAN AIR

We have learnt the importance of good, clean food. A plentiful supply of fresh, clean air is equally necessary. There is no difficulty about this among people who live open-air lives, but under the artificial conditions of civilization it is often necessary to take special care to ensure a plentiful supply of fresh air. We have seen that nearly all impurities in air are harmful, and that the most dangerous impurities are the organisms which spread disease from one person to another. Such diseases can only be spread if people breathe in air which has already been breathed out by a diseased person.

Ventilation

The first step towards preventing the spread of 'airborne diseases' (i.e. diseases whose germs float in the air) is to ensure that air which has recently passed through one person's lungs is not re-breathed by someone else. This is ensured by proper *ventilation*, i.e. by changing the air frequently and thus reducing the risk of infection.

In tropical countries, there need be little difficulty about getting plenty of fresh air. Buildings with open sides, or with plenty of doors and windows on two or three sides, allow fresh air to flow through from outside, and this natural ventilation is usually quite adequate in well-planned buildings. The ventilation of sleeping-rooms at night is just as important as that of rooms used in the daytime. Some people think that 'night-air' is unhealthy, so they close all their windows at night and sometimes even cover up their heads as well. This is quite wrong, and it is just as important to breathe fresh air at night as in the daytime, hence windows of sleeping-rooms should be kept open. (The use of bars, or 'expanded metal', will prevent thieves from entering.)

In tropical countries, artificial ventilation is usually only necessary in large halls, e.g. cinemas, that are crowded with people. Under such conditions, electric fans have to be used. These should be arranged so as to blow in fresh air or to draw out breathed air. When artificial ventilation is used, there should be a supply of *at least* 1,000 cubic feet of fresh air per hour for each person in the room, but two or three times this amount is better.

The cooling effect of ventilation

We have seen that one important reason for ventilation is the need to reduce the danger of spreading infection by air-borne diseases.

Another very important reason for ventilation is connected with the physical condition of the air—its *humidity*, its *temperature*, and its *movement*. It was formerly thought that a badly-ventilated room feels uncomfortable because the breathed air contains less oxygen and more carbon dioxide than fresh air. Experiments have shown that this explanation is wrong; even the worst-ventilated rooms never contain sufficient carbon dioxide to do any harm. If you entered a room containing only 13 per cent. oxygen (as against 21 per cent. oxygen out-of-doors) you would not notice the difference; in fact so long as the air inside a room contains more than 10 per cent. oxygen a man feels much the same as in the fresh air outside. So lack of oxygen is not responsible for the discomfort one feels through lack of ventilation. A crowded and badly-ventilated room feels uncomfortable because (*a*) *the temperature of the air is too high*, (*b*) *there is too much water-vapour in the air*, and (*c*) *the air is not in motion*. In the tropics, the main aim of ventilation is to *keep the air moving, since the main effect of bad ventilation on bodily comfort is due to lack of cooling power*.

In Chapter Four we learnt that Man is a 'warm-blooded' or 'constant-temperature' animal, and that the body-temperature is regulated mainly by the loss of excess heat from the skin. (Roughly 75 per cent. of the heat produced in the body is given out by way of the skin.) Some of this excess heat is got rid of by conduction and radiation, the capillary blood-vessels in the skin being flooded with blood when the body-temperature rises under warm outside conditions. (see also p. 103). The most important method of getting rid of excess heat, however, is by the evaporation of sweat, the necessary *latent heat* being taken from the skin. But in order to produce a cooling effect, *the sweat must evaporate*, and in a badly-ventilated room, filled with still, damp air, the sweat cannot evaporate fast enough to cool the body sufficiently.

The main problem of ventilation, therefore, is to increase the *cooling power* of the air; hence, *while good ventilation should provide a plentiful supply of fresh air, it is also necessary that this air should be constantly moving*.

Fig. 59 shows an important experiment illustrating these principles. A man was placed in a room which was divided into two parts A and B by a hanging curtain of non-porous material. In one experiment, cool, dry air (i.e. 'fresh' air) was passed through B (i.e. over the man's *body*), and warm, damp air containing nearly 1 per cent. carbon dioxide (i.e. 'foul' air) was passed through A, yet *the man felt no discomfort although he was breathing 'foul' air*. In a second experiment, 'fresh' air was passed through A and 'foul' air through B, and *the man felt uncomfortable although he was breathing 'fresh' air*. These two experiments show clearly that the main effect of ventilation is on the *skin* and *not* on the lungs.

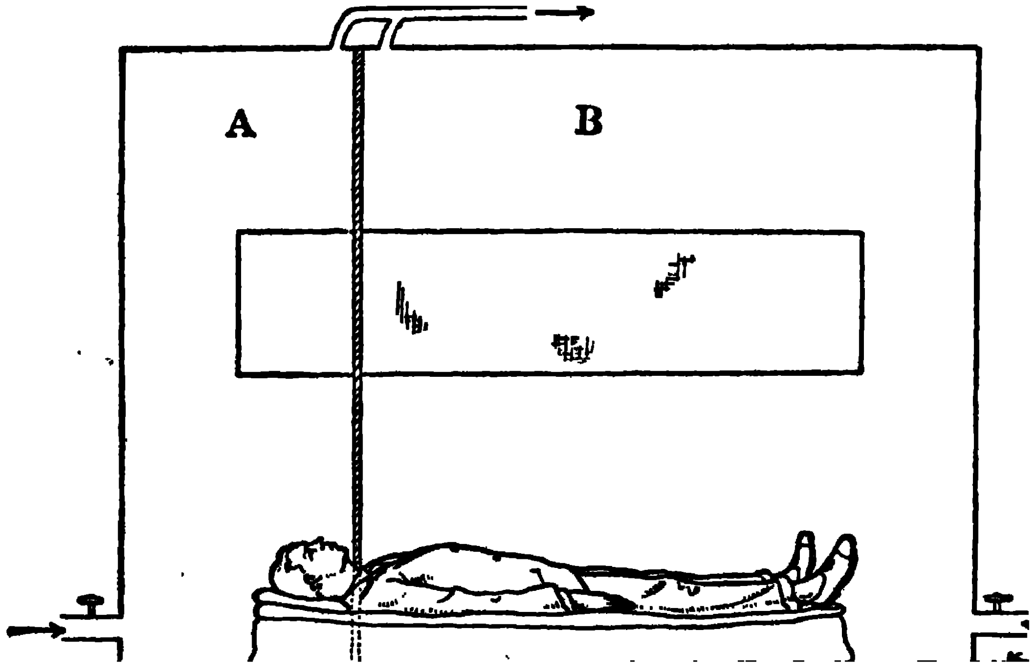


FIG. 59.—'The man in two rooms'

People doing hard physical work under very hot and very humid conditions may suffer from *heat-sickness* or *heat-exhaustion*, the commonest form being *heat-stroke*, when there is high fever owing to the failure of the circulatory system. The victim, however, usually recovers rapidly after removal to a cool place, especially if the skin is sprinkled with water and then cooled by fanning.

Heat cramp is another complaint that affects people working under hot conditions, e.g. stokers in ships' engine-rooms, miners, iron- and steel-workers. Heat cramp is brought on by drinking large quantities of water to quench the thirst caused by excessive sweating. Sweat contains salt, so that during heavy sweating not only is much water lost from the body but also a lot of salt. If large quantities of salt-free water are then drunk the concentration of salt in the blood is reduced and this may cause muscular cramp. Heat cramp may be prevented by drinking dilute salt solution instead of plain water (using about one part of common salt to 500 parts of water, i.e. one teaspoonful of salt to one pint of water).

DISEASES WHICH ENTER THE BODY THROUGH THE AIR-PASSAGES

The respiratory tract (like the food-canal) is really part of the external environment, there being direct communication between the nose, throat, and lungs and the outside air. As a result of this, the germs of a number of diseases can enter the body by way of the air-passages, although there is very little danger of infection if clean, fresh air is breathed. Fresh air, out-of-doors, contains comparatively few bacteria of any kind. Disease-producing bacteria, in particular, soon die in fresh air and sunlight. But in badly-ventilated and over-crowded rooms, the air often contains many disease-producing bacteria—floating on particles of dust or in tiny drops of water—and a healthy person may breathe in sufficient of the bacteria to catch the disease. Infectious diseases like the common cold, influenza, measles, whooping-cough, diphtheria, smallpox and consumption are usually spread in this way.

During normal, steady breathing, the breathed-out air contains very few bacteria, since the damp, sticky surfaces of the air-passages (particularly the nose-cavity) hold back nearly all the solid particles. But when air is forced out suddenly, as in sneezing, coughing, or even speaking, some of the liquid lining the air-passages is blown out as a fine spray of tiny drops of mucus and saliva. In this way an infected person, while coughing or sneezing, produces a spray of infected *droplets*, containing millions of bacteria. By the proper use of a handkerchief, however, most of these droplets can be caught as they leave the mouth and nose, otherwise the spray may travel some distance, and healthy persons within five or six feet may breathe in enough infected droplets to catch the disease. '*Droplet infection*' is the commonest way in which people catch what were formerly called 'air-borne' diseases.

There are several ways of preventing the spread of diseases by *droplet infection*: (i) People who are coughing or sneezing badly should isolate themselves, e.g. stay at home, or better still, stay in bed; (ii) the proper use of a handkerchief will trap the infected droplets; (iii) rooms should be properly ventilated; (iv) overcrowding should be avoided, so as to keep healthy people beyond 'spraying distance' of infected people (e.g. sickness in the British Army was greatly reduced when the distance between soldiers' beds in barracks was increased to over three feet); (v) by having clean, dustless surroundings. In clean, dust-free air, most of the droplets fall to the ground and do no further harm; but if the room is dusty, when the dust is stirred up the infected dust-particles float about in the air and spread infection.

Diphtheria.

This infectious disease, which is commonest in temperate climates, is caused by diphtheria bacteria that attack the lining of the nose, throat, and wind-pipe (see Fig. 60). Diphtheria is commonest and most dangerous in young children between three and five years of age. The disease is usually spread by droplet infection from the sick to the healthy. Children may also become infected by drinking from an infected cup or sucking an infected pencil. Diphtheria bacteria can also live on books and furniture, e.g. on door-handles. Unfortunately, some people are *diphtheria carriers*, being infected with the germ although they appear quite healthy. Such '*healthy carriers*' can infect others by droplet infection when they cough or sneeze.

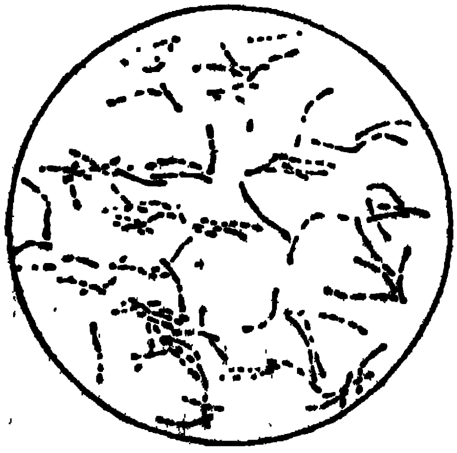


FIG. 60.—Diphtheria bacteria (highly magnified)

Copyright, by permission of Burroughs Wellcome & Co. (The Wellcome Foundation Ltd.)

A few hours or days after infection the patient develops a sore throat and a rise in temperature. As the bacteria multiply, they form a greyish-white film across the throat, which, in bad cases, may block the windpipe. By examining the saliva and mucus on the back of the throat a doctor can find out whether a 'sore throat' is due to diphtheria bacteria or not.

If diphtheria bacteria are present, *diphtheria anti-toxin* is injected into the patient. This is made by cultivating diphtheria germs, and then filtering the culture to separate the bacteria from the poisonous substance (or *toxin*) they produce. This *toxin* is injected, in small doses, into a healthy horse, which gradually produces in its blood an *anti-toxin* to neutralize the toxin. Blood is then taken from the horse and filtered to remove blood-cells and any possible bacteria, and the filtrate, containing the diphtheria anti-toxin, is packed in sealed tubes and sent to doctors and hospitals for use when required.

Owing to the rapidity with which diphtheria develops, it is most important that the anti-toxin should be injected into the patient's blood-stream as soon as possible. One day's delay may make all the difference between the life and death of the patient. Every child with a sore throat, therefore, should be examined by a doctor *at once*. As the anti-toxin injection is harmless and will also prevent a healthy person from catching diphtheria during the following few weeks, it is usual to inject it into anyone who has been in contact with a diphtheria case. This injection gives protection (*passive immunity*) against diphtheria infection for a few weeks only. After the throat is qu[illegible]tter, a diphtheria patient has to be kept very quiet for at least a month, because there is a danger that the heart muscle may become permanently weakened.

A child of 9–12 months can be made *actively immune* to diphtheria by another simple and harmless treatment consisting of two or three injections of a different preparation of diphtheria toxin and anti-toxin. This immunity takes a few months to develop but it lasts for years. The *Schick Test* enables a doctor to tell whether a child is immune to diphtheria or not, and if this test is repeated once a year it is possible to give a child complete protection against this disease. Notice that this toxin-anti-toxin treatment causes *your body* to produce anti-toxins capable of destroying the disease germs. When the body becomes immune in this way by producing its own antibodies, it is said to have acquired *active* immunity.

Measles

The actual organism which causes *measles* has not yet been isolated. It is something that passes through the finest filters—smaller than any known bacteria—and it is called a *virus*. Measles attacks children more frequently than adults and is usually spread by droplet infection or by actual direct contact with a case of measles. About fourteen days after infection, the patient develops what appears to be a bad cold, with a running nose, red and watery eyes, a slight cough, and a rise in temperature. This early stage is the most infectious. On the third or fourth day of the cold, red spots appear on the skin, first on the face and behind the ears, and the spots then spread to the neck and other parts of the body. These spots fade away after a few days as the patient recovers, but he is still infectious for another ten days.

Measles itself is not a very dangerous disease, but the patient needs careful nursing if dangerous after-effects are to be avoided. Measles sometimes leads to *bronchitis* (inflammation of the lining of the wind-pipe), and to *pneumonia* (inflammation of the lungs [1]). If there are discharges from the ears there is a danger of ear-disease and deafness. Owing to the long delay between infection and the appearance of the outward signs of the disease, and the very infectious stage before the spots appear, measles is a very difficult disease to prevent or control.

One attack of measles causes the body to produce substances (antibodies) capable of destroying measles germs, and these antibodies remain in the body throughout life and make it *immune* to measles. Since the body becomes immune by producing its own antibodies, we say that it has acquired *active* immunity.

Whooping-cough

This is another very infectious disease which mainly affects young children. Whooping-cough is spread by droplet infection, and, as in the case of diphtheria, the risk of infection is increased by the existence of 'healthy carriers' of the germ. Between one and two weeks after infection, the patient develops what seems to be an ordinary cold and slight cough, and this early stage is the most infectious. It is not until about ten days later that the long attacks of coughing begin, each attack ending with the characteristic 'whoop' as air rushes into the empty lungs. As with measles, whooping-cough itself is not dangerous if the patient is carefully nursed, but it is the after-effects that may be serious. If the coughing is very violent and lasts for a long time, the lungs may be damaged, thus causing the risk of pneumonia or consumption, which may kill the patient.

A patient suffering from whooping-cough can infect others for a period of six weeks. Owing to the very infectious stage before the characteristic 'whooping' begins, whooping-cough is a very difficult disease to prevent or control. One attack of whooping-cough usually makes the body immune to further attacks.

---

[1] Any germ (e.g. measles or influenza) that multiplies in the lungs may cause pneumonia, but most cases, where pneumonia does not follow another disease, are caused by pneumonia bacteria.

Smallpox

In some tropical countries, smallpox is one of the most dangerous diseases, sometimes killing more people than cholera, plague, and dysentery combined. But in countries where *vaccination* is the rule, smallpox is very rare. The germ of smallpox has not yet been isolated, but it is believed to be a *virus*. Smallpox is one of the most infectious of all diseases. The germs are present in the lining of the patient's mouth, throat, and nose, and are scattered by the spray of droplets during sneezing and coughing. Besides this, germs are also present in the skin, and as dead scales of skin may float about in the air the germs can be carried over long distances in this way. Hence, smallpox is one of the few diseases which are really 'airborne'. (Most of the diseases that used to be called 'air-borne diseases' are spread by droplet infection.) This makes smallpox extremely infectious, and if an un-vaccinated person merely enters a room in which a smallpox sufferer is present, he is almost certain to be infected. Smallpox germs can remain dry for months without being killed; in this way clothing, books, papers, &c. remain infected for a long time.

About two weeks after infection, the patient develops headache, backache, and a rapid rise of temperature. Two or three days later, the typical smallpox spots or 'pocks' appear on the face, hands, and feet. These are small, hard 'pocks', and feel like small shot under the skin. They soon fill with pus and become surrounded with an inflamed ring. The patient has high fever for several days, and many smallpox cases die at this stage. If the patient recovers, the skin is 'pock-marked' for life.

After recovery, a smallpox patient must be isolated until all the scales of dead skin have disappeared from round the 'pocks'. This takes from three to four weeks. The patient is then immune to further attacks.

Smallpox can be almost entirely prevented by *vaccination*, which prevents people from catching the disease, or, if they do catch it, from having a severe attack. Vaccination consists of introducing the germ of a similar but milder disease—*cow-pox* (or *vaccinia*)—into human beings. Vaccination was introduced by an English doctor named Jenner, in 1798. He noticed that those who worked among cows often suffered from a mild disease—cow-pox—which they caught from the cows. He noticed, too, that people who had suffered from cow-pox very seldom caught smallpox, which in those days was a very common disease in England. He then carried out experiments on *vaccination*, introducing liquid from cow-pox spots into human beings, and it was found that these vaccinated people became protected from smallpox infection. Nowadays, the *vaccine lymph* used for vaccination is obtained from healthy calves or from unhatched chicken embryos and is carefully prepared and tested so that it is free from bacteria.

In countries where everyone has to be vaccinated, smallpox has been almost rooted out. If a person is re-vaccinated every few years, he is almost completely protected against smallpox.

Chicken-pox

Chicken-pox is a different and much milder virus disease, which attacks mainly children. It is usually spread by droplet infection, or by direct personal contact. About two weeks after infection, spots appear, mainly on the trunk, and these soon turn into watery blisters which become covered with a crust and dry up in a few days. The patient is still infectious until all the crusts have fallen off and all the sores have healed up. Although chicken-pox is only a mild disease, all cases should be reported to a doctor, because a mild case of smallpox may be mistaken for chicken-pox and thus produce severe smallpox in others. Since chicken-pox very seldom attacks adults, anything that looks like chicken-pox in an adult should be treated with the respect due to smallpox, i.e. a doctor must be called in *at once*. Vaccination does not protect against chicken-pox.

Tuberculosis and consumption

John Bunyan (1628–88), who wrote *The Pilgrim's Progress*, called tuberculosis 'Captain of the Men of Death', and this disease still remains one of Man's worst enemies, because it is commonest and most fatal between the ages of fifteen and forty-five, which should be the best and most useful years of a man's life. Tuberculosis, also, may attack almost any organ and tissue of the body, although the commonest form is *tuberculosis of the lungs*, which is called '*consumption*'. Domestic animals also may suffer from forms of tuberculosis, although the disease is rare in sheep and goats.

Tuberculosis is caused by *tubercle bacteria*, discovered by Koch in 1882. By special staining methods, the germ of tuberculosis can be definitely recognized under the microscope (see Fig. 61). Before anyone can become infected with tuberculosis the *tubercle bacteria* must enter the body.

There are two main ways in which it can be carried: (i) *along with the air during breathing*, or (ii) *along with food and drink*. When a consumptive person coughs or sneezes, unless he takes special care, anyone within a few feet of him may breathe in some of the droplets containing millions of tubercle bacteria. Another mode of infection is by breathing infected dust. When a consumptive person spits, the sputum contains millions of tubercle bacteria. (Laboratory tests on sputum lying in the streets of one tropical city showed that tubercle bacteria were present in 4 per cent. of cases.) If this sputum is allowed to dry up, it may be carried about as dust. Dried sputum from a consumptive person may remain infective for twenty weeks, even when mixed with dust and exposed to sunlight. In damp, dark places tubercle bacteria may survive for as long as a year. This infected dust may be breathed in by healthy people or may fall on foodstuffs. It may even be carried by insects, and living tubercle bacteria have been found in or on house flies fifteen days after contact with infected sputum. For this reason, spitting in public places is forbidden by law in some countries.

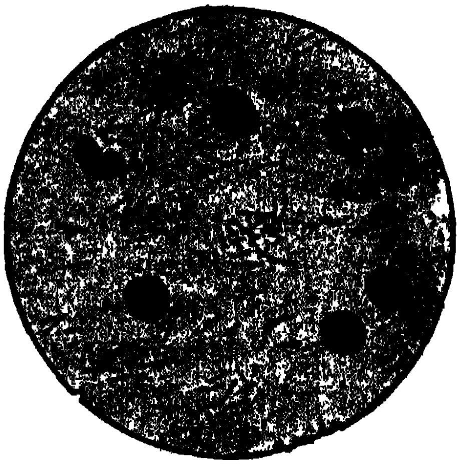


FIG. 61. — Tubercle bacteria (highly magnified)

Copyright, by permission of Burroughs Wellcome & Co. (The Wellcome Foundation Ltd.)

The germ of tuberculosis sometimes enters the body by way of the food-canal, along with infected food and drink. Cows often suffer from a form of tuberculosis, and as the germs pass out with the milk, this infected milk is dangerous. The meat of such an animal will also be infected. For this reason, careful inspection and control of tuberculous milk and meat is carried out by public health authorities.

The chief ways in which the spread of tuberculosis can be prevented are: (i) *By increasing the power of resistance to infection* by plenty of suitable food, plenty of fresh air and sunshine, and good conditions of housing and living. People in good health, living under good conditions, need have little fear of infection. (ii) *By preventing the spread of infection.* The germs of the disease are usually in the patient's lungs, and he can spread them if he spits or coughs or sneezes without proper care. Hence careless spitting should be strongly discouraged, and anyone suffering from consumption should always spit into a special vessel containing disinfectant or into paper handkerchiefs which can be burnt. He should also keep his own feeding-vessels separate from those of other people, being particularly careful that they are washed separately.

The great danger about tuberculosis is that a patient may be infected for a long time without showing clear signs of the disease—merely having a slight cough and a tired feeling. Yet it is at this early stage that there is the best chance of curing the disease. But by the time that most cases are brought to the notice of a doctor, the disease is far advanced. The patient has a severe cough and spits in an effort to clear his lungs. He readily becomes short of breath, his temperature rises each evening and he sweats in the night. He gradually loses his appetite, suffers from indigestion, and steadily loses weight.

When the disease reaches this advanced stage it can often be checked but it can seldom be completely cured.

The most important remedy in the treatment of tuberculosis is *complete rest*, and in some cases surgical methods are used to rest the diseased lung itself.

Since tuberculosis is such a difficult disease to cure, it is all the more important to take every possible step to *prevent* it. One of the most powerful weapons in fighting the spread of tuberculosis is *education* in healthy living. The disease is always associated with bad housing conditions, over-crowding and under-nutrition. One of the most remarkable things about tuberculosis is that Man has a natural resistance to the disease and that repeated heavy doses of infection are necessary to overcome this resistance. Few people escape infection by tubercle bacteria some time or other, but only a small proportion of such people actually suffer from tuberculosis, because if the first infection is by a relatively small number of tubercle bacteria it is overcome by the body's natural resistance, and subsequent light infections stimulate the formation of additional 'acquired resistance' until such a person becomes almost immune to quite large doses of tubercle bacteria. So there is little danger from occasional chance meetings with tuberculous people or from being near them out-of-doors or in well-ventilated rooms (where any germs are well diluted with fresh air). The great danger lies in getting so large a dose of tubercle bacteria as to overcome one's natural and acquired resistance.

A promising method of protecting people from tuberculosis is by vaccination with B.C.G. (Bacillus Calmette Guerin), which is a harmless variety of the tubercle germ, and in some countries B.C.G. is given to all school-children who have never been infected. By applying a simple and harmless skin reaction, the *Tuberculin Test*, a doctor can tell whether a person has ever been infected with tubercle bacteria. If this tuberculin test is positive, an X-ray examination will show whether there are any signs of active tuberculosis, or whether the patient's natural or acquired resistance has succeeded in overcoming the infection. If the tuberculin test gives a negative result, then the person can be given B.C.G. to produce, after some weeks, a strong resistance to tuberculosis. B.C.G. vaccination, therefore, can give artificial protection where it is most needed, among people who have not already built up some natural protection and who are likely to be exposed to tuberculous infection, e.g. school-children, infants living with tuberculous parents, hospital staffs, and medical students.

Tuberculosis is largely a disease of towns and cities and it is much less common among dwellers in the open country. This fact gives rise to special danger when country people go to live and work in crowded towns and are suddenly exposed to massive infection before they have had a chance to build up their resistance gradually as a result of small doses of infection, sufficient to give protection but not enough to cause the disease.

Sore throat

Most people regard a sore throat as unimportant, but most sore throats are infectious and may be the beginning of more serious diseases, e.g. diphtheria. Hence, every child with a sore throat should be seen by a doctor.

The common cold

The common 'cold in the head' is not caused merely by cold conditions but by infection with a germ or virus. When the germs multiply in the lining of the nose and throat they produce inflammation, and we say that the patient has a 'cold'. Colds are usually spread by droplet infection and by breathing infected dust. The spread of the infection can be prevented by the same methods as other 'air-borne' diseases, and also by avoiding dust and draughts, exposure to cold and wet, and rapid changes of body temperature, e.g. by sitting lightly clad in a current of air after taking vigorous exercise. The danger of colds is that they weaken the patient's resistance to infection by other more dangerous diseases; so a cold must never be neglected.

Also, some more serious diseases begin with what seems to be a common cold. Immediate home treatment will usually prevent such complications, and the patient should rest (in bed, if possible), drinking plenty of liquid, and sleeping under a blanket to encourage sweating. A drink of hot water containing lime-juice, before going to sleep, will help to make you sweat. Do not take any other medicine unless ordered by a doctor. If you 'catch cold' frequently, you should see a doctor.

Influenza

Influenza is an extremely infectious virus disease which spreads from the sick to the healthy by droplet infection in coughing or sneezing. The world-wide outbreak in 1918 killed 18,000 people in London alone: in India 6,000,000 died of influenza. In fact, more people died from influenza than were killed during the 1914–18 World War.

A few hours after infection, the patient develops headache, aching pains in the back and legs, and a high temperature. He should see a doctor at once. One type of influenza attacks the nose, throat, and lungs like a common cold. Another type attacks the food-canal. A third type attacks the nervous system. The second and third types of influenza are like dengue (see p. 179) in their outward signs. An influenza patient should go to bed at once and try to avoid infecting others when coughing, sneezing, or spitting. To lessen the risk of infection, healthy people should avoid overcrowding and lack of ventilation. People that refuse to 'give in' to a cold or to 'flu and try to carry on as usual are a danger to themselves and to the community. The quickest way to get better is to rest in bed, and this is also the best way to isolate the patient and to prevent him from infecting other people. The handkerchief, if properly used to cover sneezing and coughing, may help to prevent droplet infection. But once a handkerchief is covered with infected *mucus* from the nose and air-passages it becomes dangerous. It infects the hands of the user and he infects everything else he handles. Every time the infected handkerchief is pulled out of the pocket and waved in the air it infects its surroundings. The best arrangement is to use paper handkerchiefs, which can afterwards be burnt or thrown down the sewer. The hands of a person suffering from any respiratory disease need to be washed even more frequently than usual.

Respiratory diseases are often spread by using drinking-cups and eating-vessels which have previously been used by a sick person. In public and communal eating-places, eating-vessels should always be washed with *boiling* water to prevent the spread of infection.

CHAPTER 9

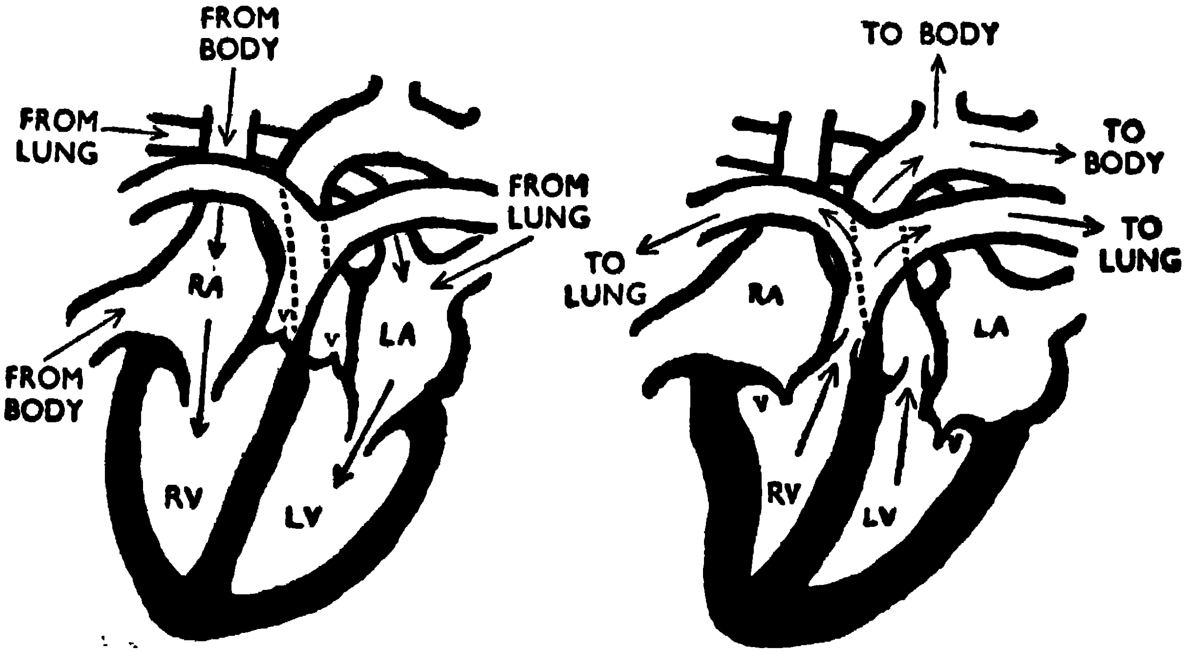
HYGIENE OF THE BLOOD SYSTEM

THE HEART

In an earlier chapter we learnt that the heart of a mammal consists of two muscular pumps lying side by side: the right heart-pump sending blood to the lungs, and the left heart-pump sending blood to the rest of the body. The human heart is a hollow muscular organ with *four chambers*, two thin-walled *auricles* above (anterior) and two thick-walled *ventricles* below (posterior). The auricles receive blood from the veins and pass it on to the muscular ventricles which then pump the blood along the main arteries (see Fig. 62).

Let us follow the course of the blood which is brought back to the heart from all parts of the body (except the lungs) by the great veins. These main veins (*two anterior main veins* and *one posterior main vein*) enter the *right auricle* and fill it with blood. The auricle then contracts and squeezes this de-oxygenated blood into the *right ventricle*. As this ventricle fills with blood, three somewhat triangular membranes float up until they meet across the opening between the auricle and the ventricle, thus forming a *valve* which stops blood from going back again into the auricle. When this valve is closed, the only opening from the right ventricle is the artery leading to the lungs. Hence, when the right ventricle contracts, blood is forced into this artery and so to the lungs. When the right ventricle stops contracting, blood might be forced back from the artery into the ventricle if this were not prevented by three cup-shaped membranes which are spread out by the back-pressure of the blood in the artery until they meet and act as a valve.

After passing through the capillary blood-vessels surrounding the air-sacs in the lungs and exchanging oxygen and carbon dioxide with the air in the lungs, the oxygenated blood returns through a large vein to the *left auricle*. When full of blood, this left auricle contracts (at the same time as the right auricle) and squeezes the blood into the *left ventricle*. As in the case of the right ventricle, when the left ventricle is full of blood a valve closes and stops the blood from returning to the auricle. Then the left ventricle contracts in turn, and forces the oxygenated blood into the main artery, the aorta, which supplies blood to all parts of the body through smaller arteries ending in capillaries. Small cup-shaped valves prevent the return of blood from the main artery into the left ventricle.



HEART FILLING HEART EMPTYING

FIG. 62.—Action of heart (diagrammatic)

RA: right auricle LA: left auricle
RV: right ventricle LV: left ventricle
V: valve

Examination of heart

Examine the heart of a large mammal, e.g. sheep or goat, obtained from the abattoir, with the blood-vessels cut off some distance from the heart. Slit open the *heart-sac* to expose the heart and identify (*a*) the ventral surface of the heart with its diagonal groove filled with fat, (*b*) the right ventricle (thin-walled and rather soft to the touch), (*c*) the left ventricle (thick-walled and therefore firm and hard), (*d*) the right and left auricles (thin-walled and divided from the ventricles by a horizontal groove filled with fat). Draw the heart as seen from the ventral surface.

Cut horizontal slices across the apex of the heart until you expose the

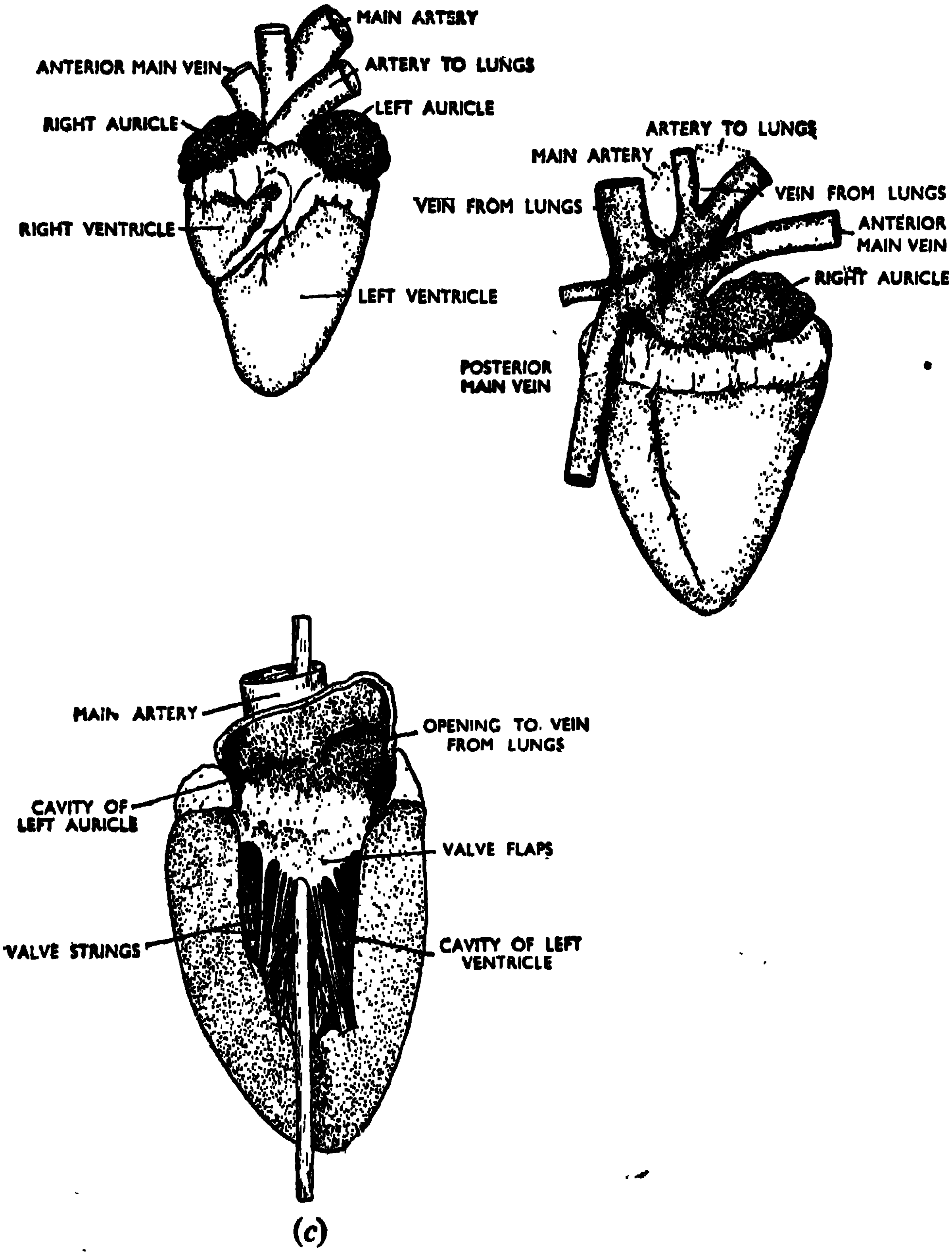


FIG. 63.—Views of sheep's heart

(*a*)—Ventral surface. (*b*)—Dorsal surface.
(*c*)—From left side, with glass rod through main artery.

cavities of both ventricles. Notice (*a*) the shape of the cross-section of each ventricle and (*b*) the relative thickness of their muscular walls. Draw what you see. Wash out the heart with water and then slit up the ventral wall of each ventricle and notice (*a*) the valve-strings and valve-flaps of the valves which separate the ventricles from the auricles (there are three valve-flaps in the right side of the heart and two in the left), (*b*) the opening of *the artery to the lungs* in the *right* ventricle, (*c*) the opening of *the main artery to the body* in the *left* ventricle. Push a thick, round-ended glass rod or a thin stick into these openings and follow the course of these two arteries.

Slit up the auricles and open up the right and left sides of the heart. Notice (*a*) the openings of the two *main veins* (anterior and posterior) into the *right* auricle, and (*b*) the openings of the two *veins from the lungs* into the *left* auricle. Follow the course of these veins by pushing a glass rod along them (see Fig. 63(*c*)).

Finally, slit open the main artery just above the left ventricle to expose the three *pocket-shaped valves* which prevent back-flow of blood into the ventricle. Pour some water on to these valves and notice how they expand to meet each other and close the opening. (*N.B.* Notice that the left ventricle has muscular walls which are about three times as thick as those of the right ventricle and capable of exerting three times the pressure, there being three times greater resistance to blood-flow round the body-circulation than in the lung-circulation.)

ARTERIES

The volume of blood pumped by the heart varies very considerably according to the amount of oxygen needed by the muscles. When the human body is at rest, the left ventricle pumps, each minute, about 2½ pints of blood into the main artery, and a similar quantity is pumped to the lungs. During violent exercise, e.g. running up a long flight of stairs, this volume may be increased three or four times in order to supply the extra oxygen needed by the muscles. Under such conditions, therefore, the pressure on the walls of the large arteries will be very great, hence arteries have strong, but elastic, muscular walls. The sudden rush of blood when the ventricles contract is most violent in the arteries nearest the heart, hence the main arteries have the thickest walls. The walls become thinner as the arteries branch and the blood flows more smoothly, until by the time the blood reaches the capillaries there is no longer any pulse, and the walls of the capillaries can be very thin, usually only one cell thick. Such exceedingly thin walls ensure close contact between the blood and the body-tissues, and the *tissue-fluid* acts as a 'middle-man' between the two. The diameter of a capillary is very little bigger than that of a single red blood-cell, and its length may be only one-fiftieth of an inch, yet in this short space between the end of an artery and the beginning of a vein the blood exchanges food and oxygen for carbon dioxide and other waste products.

In Man, the *main artery* (or *aorta*) is about one inch in diameter and its walls are about ⅛ inch thick. It arises from the left ventricle, and soon after leaving the heart it gives off (i) left and right branches carrying blood to the head, and (ii) left and right branches carrying blood to the fore-limbs. The main artery now turns over to the left and continues down the body, close to the backbone, passing through the diaphragm, into the belly-cavity (or abdomen).

Immediately after passing through the diaphragm, the main artery gives off a branch artery to the *liver* and *stomach* and, a little farther on, it gives off branch arteries to the *intestine*. About the same region, the main artery gives off left and right branches to the *kidneys* and, farther on, to more branch arteries which supply blood to the legs (see Fig. 11).

VEINS

The arteries carry blood away from the heart, and the capillaries join the arteries to the veins, which return the de-oxygenated blood to the heart. The blood from the capillaries has a very low pressure and no 'pulse', hence there is no need for the veins to have thick, strong walls. Veins have only a thin layer of muscle round them, and the flow of blood back to the heart is assisted by the pressure of the body-muscles and by pocket-like *valves* (rather like the valves in the large arteries where they leave the heart) (see Fig. 64). During exercise, as the muscles move, they press on the veins and so squeeze the blood along towards the heart, the valves preventing 'back-flow'. Breathing movements also help in returning venous blood to the heart (see also p. 157). Three main veins enter the *right auricle*. The two *anterior main veins* (left and right) bring blood from the upper part of the body, while the *posterior main vein* brings blood from the lower part of the body. Each anterior main vein receives several branch veins: (i) two veins which carry blood from the head, and (ii) veins carrying blood from the *arms* and the *walls of the chest-cavity*. The posterior main vein lies close to the main artery in its course down the body and receives (*a*) a vein from the *liver*, (*b*) two veins from the *kidneys*, (*c*) veins from the *back*, and (*d*) veins from the *legs*. Another important vein, the *hepatic portal vein*, has already been mentioned on p. 83.

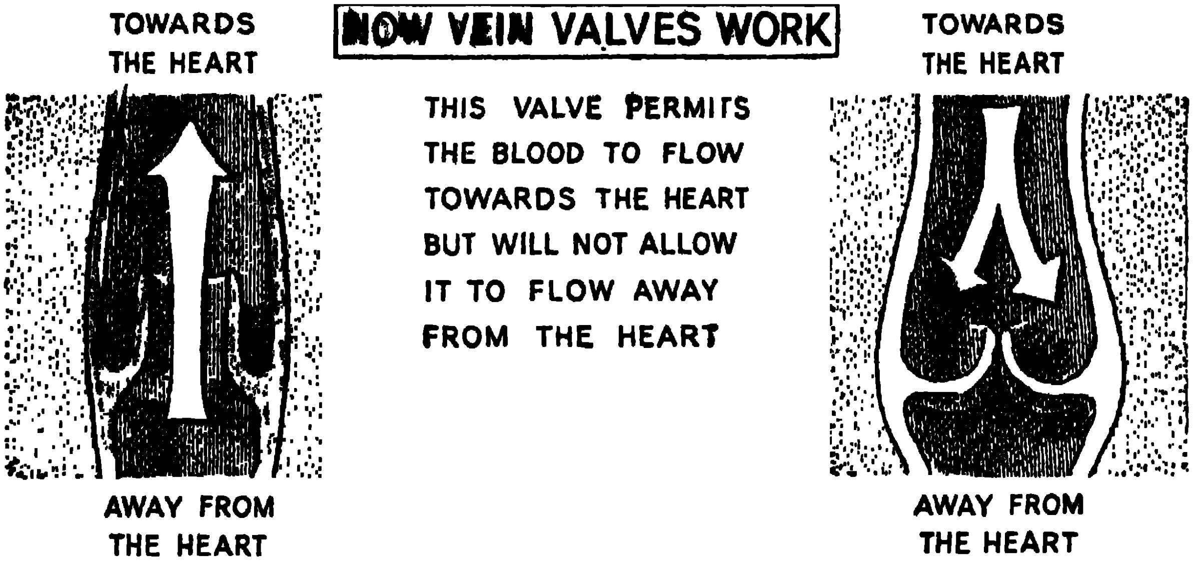

HOW VEIN VALVES WORK
TOWARDS THE HEART
AWAY FROM THE HEART
THIS VALVE PERMITS THE BLOOD TO FLOW TOWARDS THE HEART BUT WILL NOT ALLOW IT TO FLOW AWAY FROM THE HEART
TOWARDS THE HEART
AWAY FROM THE HEART

FIG. 64.—Vein valves

THE CLOTTING OF BLOOD

Although blood is a liquid when in the blood-vessels, after escaping it soon sets to a jelly-like *clot*. Thus, if blood is collected in a beaker and is allowed to stand for 5–10 minutes, the beaker can then be inverted without any blood running out. The blood clots owing to the formation of a network of fine threads of *fibrin* (an insoluble protein, formed from *fibrinogen*, a soluble protein contained in the blood) when blood is exposed to the air. This net of fibrin threads spreads itself round the blood-cells. After the blood has stood for some time, the fibrin threads contract so that the clot contracts also, squeezing out a clear yellow liquid called *serum*.

Clotting is the natural first aid to the healing of wounds, since the blood-clot plugs the wound and the fibrin network forms a foundation for the growth of new tissue.

HYGIENE OF THE BLOOD SYSTEM

We have seen that the blood system is concerned with *transport*. It carries the necessities of life—food, water, and oxygen—to all parts of the body. It carries food from the intestine and oxygen from the lungs to the body tissues and it removes waste products. It distributes heat produced in working muscles and so regulates the temperature of the body. By the action of its white cells and certain complex chemical substances, the blood forms a defence against infection.

With a sufficient and suitable diet and a healthy digestive system, the blood receives the necessary food for distribution. With a plentiful supply of fresh air and proper breathing, the blood gets the necessary oxygen. The next thing is to ensure an efficient *circulation*. The heart pumps blood through the main artery and its branches until it reaches the capillary blood-vessels. By the time the blood reaches the capillaries the pumping action of the heart is no longer felt and the blood pressure in the capillaries is much lower than in the larger arteries. The blood is collected from the capillaries by the veins and returned to the heart. *This blood is not forced back through the veins by the pumping action of the heart but by the movement of the body-muscles and the diaphragm.* When the muscles shorten and thicken they press upon the veins and, owing to the valves in the veins, the blood is driven towards the heart (see Fig. 64). If we stand perfectly still for a long time, we become very uncomfortable and may even faint. This is because, without muscle movements, the blood collects in the veins of the lower part of the body and in the lower limbs, thus making the circulation less efficient. In practice, we usually change our position slightly from time to time to help the circulation. The return of blood to the heart is also helped by the movements of breathing. We have seen that, in breathing, the ribs are raised forwards and upwards, while the diaphragm contracts and flattens. The chest-cavity is thus enlarged, but at the same time the abdominal cavity is made smaller. This pressure on the contents of the abdomen forces blood from the large veins up to the right side of the heart. When air is breathed out from the lungs, the greater pressure in the chest-cavity will hinder for a moment this flow of blood to the right side of the heart; but as soon as air is breathed in, the lower pressure in the chest-cavity will 'suck' blood into the three main veins leading to the heart.

Breathing movements also help the circulation of blood through the lungs, since when air is being breathed out of the lungs, the greater pressure in the chest-cavity drives blood along the veins leading from the lungs to the left side of the heart.

The importance of muscular exercise

Without exercise, a man cannot keep up an active circulation of the blood. If a man is kept perfectly still in an upright position (e.g. tied to a post), he dies after a time owing to the failure of his circulation. This happened in the Roman punishment of 'crucifixion', a slow and painful death by hanging a person on a wooden cross. One of the most important effects of active exercise—playing games, walking, running, swimming, cycling, &c.—is that it improves the circulation of the blood, and the more efficient the transport system, the healthier the body and brain will be.

FAINTING AND SHOCK

The main reservoir of blood in the body is contained in the blood-vessels of the stomach, liver, spleen, and intestines, and this region is so richly supplied with blood-vessels and blood that at any one moment it may have in it from one-sixth to one-third of all the blood in the body. When the walls of these blood-vessels contract, more blood is forced to the brain, e.g. if a man is carefully balanced while lying on a 'see-saw' and then given a problem in mental arithmetic, his head-end overbalances because more blood flows to the brain from the central reservoir. Fainting (or mild *shock*) is caused by an insufficient blood supply to the brain, hence first aid consists in placing the patient with his feet higher than his head and pressing gently on his abdomen. Suddenly standing upright after lying down quietly for some time may cause momentary faintness because it takes a fraction of a second for the abdominal blood-vessels to contract and prevent blood draining down away from the brain.

Shock is a result of the body's reaction to injury or emotional upset, when the circulation slows down, thus reducing the oxygen supply to the tissues. After severe injury, there is often a serious loss of fluid from the blood system, so less blood is returned to the heart, which delivers less blood to the main abdominal reservoir and to the extremities of the body (e.g. the brain). The blood pressure falls, the pulse slows down, and the patient's skin becomes pale and cold. Severe shock is best treated by restoring the lost blood volume. This is done by *blood transfusion*, and hospitals therefore keep a stock of blood in immediate readiness for urgent cases. *Whole blood* is transfused whenever large amounts of blood have been lost through accident, injury, childbirth, or certain diseases (e.g. *anaemia*, a condition in which there is a deficiency of red blood-cells). Blood for transfusion is drawn from a healthy person, a substance is added to prevent clotting, and the blood is stored in a refrigerator at a temperature of from 4° to 6° C. Under these conditions it may be kept for about three weeks. When a patient requires a whole-blood transfusion, he must have blood that matches his *blood-group*. There are four main groups of blood—A, B, AB, and O—and a patient with a group A blood must be given group A blood, a group B patient must have group B blood, and so on. Under certain conditions, however, group O blood may be given to group A or B or AB patients. Mixing blood from the wrong groups causes the red blood-cells to cluster or clump together, and this may have fatal results. So before a blood transfusion is given, samples of the patient's and the donor's blood are first mixed under a microscope to see that the red blood-cells do not clump.

Plasma (the liquid portion of blood from which the blood-cells have been removed) can be dried or frozen and thus keeps better than whole blood. This plasma is often used instead of whole blood for replacing fluid lost from the blood, e.g. in accident cases out of reach of a hospital and for treating shock resulting from severe burns. Since plasma contains no blood-cells, it does not need to be matched with the patient's blood.

Blood transfusions now save so many lives that the supply of human blood for medical use has become an important branch of public health. But blood cannot be made artificially; the only source of supply is human veins. So every healthy citizen should be willing to give a little of his blood to his local 'blood bank', ready to save a fellow-citizen's life. Most people can spare a pint of blood without any discomfort or ill-effects; this pint of blood can mean the difference between life and death to a fellow-citizen.

WOUNDS AND BLEEDING

In mammals, the blood circulates in a closed system of tubes—the blood-vessels. If a blood-vessel is cut, the blood escapes, and if the damaged blood-vessel is large, the loss of blood may be serious.

With small cuts and scratches where only small blood-vessels have been damaged, bleeding soon stops owing to the clotting of the blood as it comes into contact with the air (see p. 156). Although there is no danger from loss of blood in such cases, there is always a danger that harmful bacteria may enter the wound, so even the smallest wounds should be treated with an *antiseptic* (e.g. weak iodine solution, which stops the growth of bacteria) and then covered with clean cotton cloth to keep out infected dirt. Moderate bleeding is a safeguard against infection, since the blood washes away germs. Dirty wounds should be washed with clean water to remove dirt or other foreign bodies.

With larger wounds, the first thing to do is to stop loss of blood. This can usually be done by applying gentle pressure to the wound by bandaging a pad of clean cotton material over the wound. As soon as the bleeding has been stopped the bandage should be loosened. If bandaging fails to stop the flow of blood, greater pressure must be applied to the damaged blood vessel. When a *vein* is bleeding (the blood escaping in a dark-red, steady stream) pressure should be applied with the thumbs to the side of the wound which is *farthest away from the heart*. Bleeding from veins is more frequently met with than bleeding from arteries, the veins being nearer the surface of the body than the arteries. The blood-pressure in the veins being only small, bleeding from a vein is easier to stop than bleeding from an artery.

Bleeding from an artery is more serious, but as the arteries are protected by the muscles, arterial bleeding is not often met with. In bleeding from a large artery, bright red blood escapes in pulses as the heart beats, and immediate treatment is necessary. In arterial bleeding, pressure should be applied with the thumbs to the side of the wound *nearer the heart*. If the wound is in the arm or leg, and the pressure of the thumbs is not sufficient to stop the bleeding, a *tourniquet* may be used. This is made by tying a bandage round the limb above the point where the thumb is pressing, and tightening it by twisting with a stick. A hard pad is put under the bandage so as to press on the artery where it passes over a bone. The proper use of a tourniquet should be learnt from a doctor by attending a first-aid course, and it is important to remember that *a tourniquet is only used in very serious cases, when a doctor should be called at once. A tourniquet stops circulation in the limb, and must not be kept tight for more than fifteen minutes at a time.*

PUS-FORMING BACTERIA—BLOOD-POISONING

We have seen that the skin separates the interior of the body from the outside world. When the skin is cut or broken, germs can enter, and some of these are harmful.

The commonest germs which enter the skin in this way are the bacteria which form *pus*. The tissues themselves are able to resist invasion by bacteria, for the white corpuscles in the lymph surround and destroy the invading bacteria; but if the invaders are too numerous the white cells die and mix with dead bacteria and decomposing body-cells to form *pus* (see Fig. 65). Sometimes these pus-forming bacteria may enter a hair-pit or a sweat-duct and, if they are sufficient in number, they form a *pimple*. If the bacteria make their way deeper and multiply more rapidly, they form a *boil*. If the pus-forming bacteria get into the blood-vessels they may be carried to other parts of the body, causing *blood-poisoning*, which is often fatal. It is important to remember that most cases of blood-poisoning result from neglected sores, cuts, and scratches, often very small in size. To avoid infection with pus-forming bacteria, first see that any wound is *clean*. The pain caused by cleansing a wound is small compared with the pain caused later by an infected wound. The person giving first aid should first wash his own hands and then wash the wound with a *clean* piece of cloth and *clean* water. Better still, wash the wound with a little *germicidal soap* or with a *mild antiseptic*, e.g. 'Dettol' or dilute sodium hypochlorite solution ('Milton'). Then bandage the wound loosely, so that air can get to it. It is very important to avoid spreading the bacteria contained in pus from sores, pimples, and boils, which should never be squeezed to get out the pus (particularly if the infection is near the lips, nose, eyes, or ears when the infection may be spread to nearby organs).

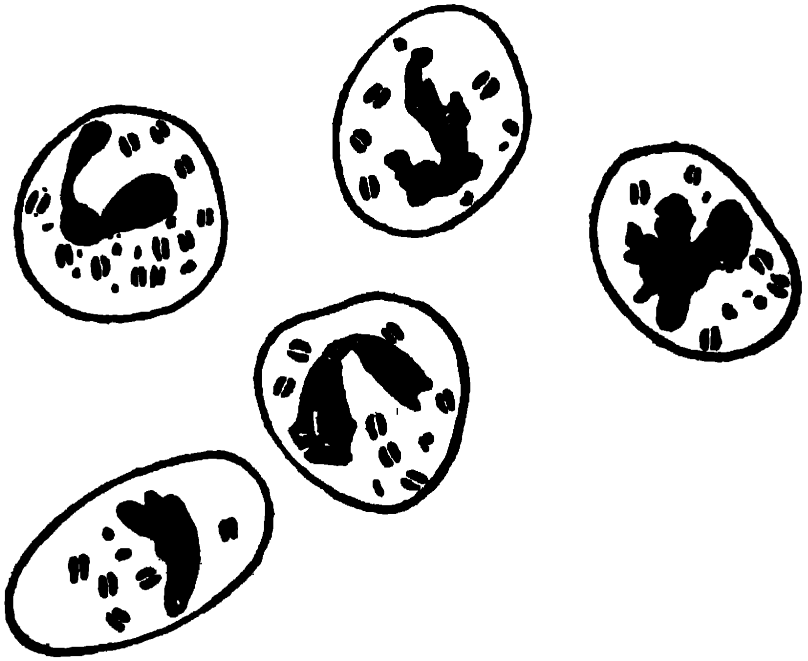


FIG. 65.—White blood-cells which have absorbed disease germs

Tetanus—Lockjaw

Besides pus-forming bacteria, *tetanus* bacteria may enter wounds, causing a very dangerous disease, *tetanus* (or *lockjaw*). Normally, tetanus bacteria live and multiply in the intestines of grass-eating animals, but without doing any harm to the animal. Some tetanus bacteria pass out with the faeces, hence the earth where such animals are kept, or cultivated soil to which animal manure has been applied, usually contains tetanus spores. Tetanus spores are a highly resistant form of tetanus bacteria which can survive unfavourable conditions for many years and still retain their ability to germinate. When the skin is broken by any dirty object (e.g. a dirty wooden splinter or a rusty nail) tetanus spores may enter. Since tetanus bacteria grow best in the absence of air, a deep hole in the flesh, which does not bleed and soon closes up, is more likely to be dangerous than a clean, open wound that is washed by bleeding and which is open to the air. Under suitable conditions, the tetanus bacteria divide and multiply rapidly, producing a very poisonous *toxin* which acts on the nervous system, first causing stiffness of the muscles of the neck and jaws. Later, the muscles of the neck, jaws and face contract and become fixed, so that the mouth cannot be opened—hence the name '*lockjaw*'. Finally, all the muscles of the body become stiff and the patient dies.

To guard against tetanus infection it is particularly important to *clean all dirty wounds at once*. Mere dabbing with a weak antiseptic will have no effect on highly resistant tetanus spores: thorough cleansing is the best safeguard. It is always risky to seal up a dirty wound with sticking-plaster, but it becomes highly dangerous if there are tetanus germs in the wound. The wound should be bandaged lightly, so that air can get in.

Deep-pierced wounds require particularly careful treatment and should be examined by a doctor, who will inject a preparation of tetanus antitoxin, when advisable, to prevent infection. (In wartime, every wounded soldier is given an anti-tetanus injection at the earliest opportunity, however slight his wound, since gunshot wounds are particularly dangerous as a source of tetanus infection.) There is also a method for producing active immunity by injecting tetanus *toxoid*, but this injection has to be given several weeks *before* exposure to tetanus infection. Whenever there is stiffness of the head and neck within three weeks of receiving a dirty wound, a doctor should be consulted at once. If an anti-tetanus injection is given in the early stages, the disease can be cured.

Snake-bite

A bite from a poisonous snake shows two wounds a short distance apart where the poison-teeth entered (see Fig. 66). (Non-poisonous snakes sometimes bite, but leave more numerous marks made by *rows* of teeth without the *pair* of larger punctures which are characteristic of poisonous snakes.) There are two main kinds of snake-poison. One kind, produced by snakes of the *cobra* group (e.g. Krait, Mamba), affects mainly the nervous system, and its effects are sometimes slow to appear, especially if the bite is on a leg. The other kind of snake-poison, produced by snakes of the *viper* group (e.g. Russell's viper, fer-de-lance), usually affects the part of the body near the bite, where a burning pain usually develops within a few minutes. If the snake can be killed and shown to the doctor treating the patient it will help him to decide on the best treatment.

Treatment for snake-bite must be immediate and, if possible, a doctor should be called at once, the victim being kept as quiet as possible in the meantime. The first thing to do is to remove as much of the poison as possible from the wound and stop it from getting into the blood-stream and poisoning the whole body. If the bite is on the leg or the arm, the limb must be *ligatured*, with a strong rubber band or bandage tied tightly, like a *tourniquet*, immediately above the bite, i.e. between the bite and the heart. (The tourniquet must not be so tight that the pulse is stopped and it should be loosened for a few minutes every quarter-of-an-hour and retied again a little further from the wound.) The next step is to remove as much as possible of the poison remaining near the bite. This is done by cutting open the flesh round the bite so that the poisoned blood flows freely. Two half-inch cuts, in the shape of a cross (+), and as deep as the snake-bite punctures, will let poisoned blood escape. After first-aid treatment has been applied, and if there is no doctor on the spot, the patient should be carried to the nearest hospital or dispensary as soon as possible.

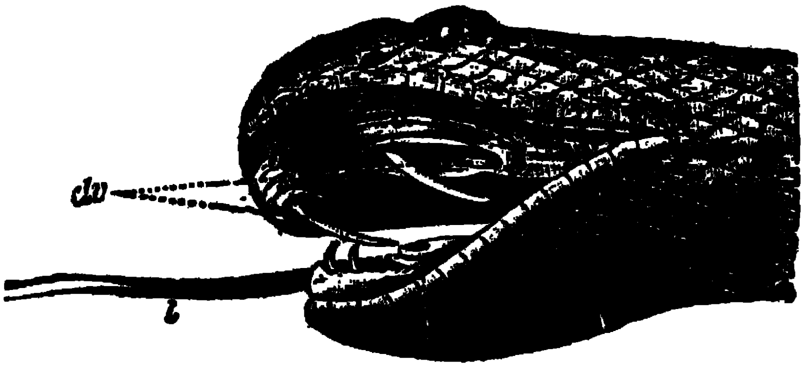


FIG. 66.—Head of poisonous snake
dv—poison-teeth. l—tongue

Scorpion stings inject a poison which affects the nervous system like cobra-poison, but it is much less dangerous and seldom causes death. Treatment should be given as for snake-bite, cutting open the wound with a clean sharp knife or razor-blade so that it bleeds freely. A few large spiders have poisonous bites, and similar treatment can be applied to get rid of as much poison as possible from the wound. Centipedes inject a different kind of poison, and bathing the wound with weak ammonia solution usually relieves the pain.

Rabies—hydrophobia

Rabies is a disease of mammals, and a man becomes infected with the disease if he is bitten or scratched by an animal suffering from rabies—usually a mad dog. (A rabid animal often scratches its mouth to remove saliva and thus infects its claws: hence the danger from scratches—as well as from bites.) The outward signs of the disease do not develop for a long time—from three to eight weeks after the bite—and if the *Pasteur treatment* is given before signs of the disease appear, the patients rarely get rabies. In countries where rabies is common, any dog-bite must be reported immediately to a doctor. The doctor thoroughly cleans the wounds and tries to destroy any germs that may have entered. He then has to decide whether the Pasteur anti-rabies treatment is necessary. If the dog cannot be traced, or if the dog is dead, he assumes that it was mad and infected with rabies and the treatment is given. If possible, the dog should be caught alive and unhurt and handed over to the health authorities to be kept under observation for ten days. If the dog is still alive and *well* at the end of this period, then it was not infected with rabies. If the dog was infected before it bit the patient, it will go mad and die in a few days, and the Pasteur treatment of the patient is necessary. In any case, it is known within ten days whether the Pasteur treatment is advisable, and there is still time for the treatment before the disease can develop.

The *Pasteur treatment* was first introduced in 1885, when Pasteur found that the *rabies virus*, contained in the spinal cord of a mad dog, could be gradually weakened in the laboratory until it no longer caused death. The patient receives an injection of the weakest virus; then, day by day, he receives injections of stronger and stronger virus, until, after two or three weeks, the patient's resistance to the disease is so increased that he becomes *immune*, and can resist the strongest virus from a mad dog.

The best way to control rabies is to control the disease in dogs. A dog can only get rabies if it is bitten by an infected animal, usually another mad dog. Hence if all the dogs in a large area are *muzzled* for a sufficient period each year, no dog can be infected, and if all the dogs entering a country are kept in strict quarantine for several months, rabies cannot be introduced. Rabies has been rooted out from England in this way.

DISEASES CARRIED BY BLOOD-SUCKING INSECTS

Many diseases are caused by the invasion of the blood-stream by tiny parasites: e.g. malaria, filariasis, dengue, yellow fever, plague, typhus, and sleeping-sickness. The main way in which these blood-parasites are carried from the sick to the healthy is by blood-sucking insects. For example, *mosquitoes* carry the germ of malaria, filariasis, dengue, and yellow fever; a *flea* carries the germ of plague; a *louse* carries the germ of one form of typhus fever; a *mite* carries the germ of Japanese river-fever (scrub-typhus); a biting *fly* carries the germ of sleeping sickness.

Since mosquitoes are one of Man's worst enemies in many tropical countries, we shall now describe a mosquito as an example of a typical insect.

MOSQUITOES

Mosquitoes belong to a very large order of insects—the two-winged flies—in which only the front pair of wings develop fully, the hinder pair of wings being reduced to a pair of tiny projections or 'balancers'. Mosquitoes are found all over the world in great numbers and in many varieties—over 1,500 different kinds being known to scientists. But practically all these different kinds fall into two main groups: (i) the *culicines* (commonly called 'gnats'), and (ii) the *anophelines* (commonly called 'mosquitoes'). As anopheline mosquitoes can transmit the *malaria parasite* they are very important in tropical countries, and we shall describe *Anopheles* as an example of this order of insects.

External features

The body of an *anopheline mosquito* (like that of any other *insect*) consists of *head*, *fore-body* (or *thorax*), and *hind-body* (or *abdomen*) (see Fig. 67).

The *head* has a pair of *compound eyes* and a pair of long, jointed *feelers*, bushy and hairy in the male, slender and less hairy in the female. Projecting from the front of the head is a '*beak*', or *proboscis*, by means of which mosquitoes take in their food. The 'beak' of a *male* mosquito consists of a slender tube and is used for sucking juices from *plants* (but *not* for sucking

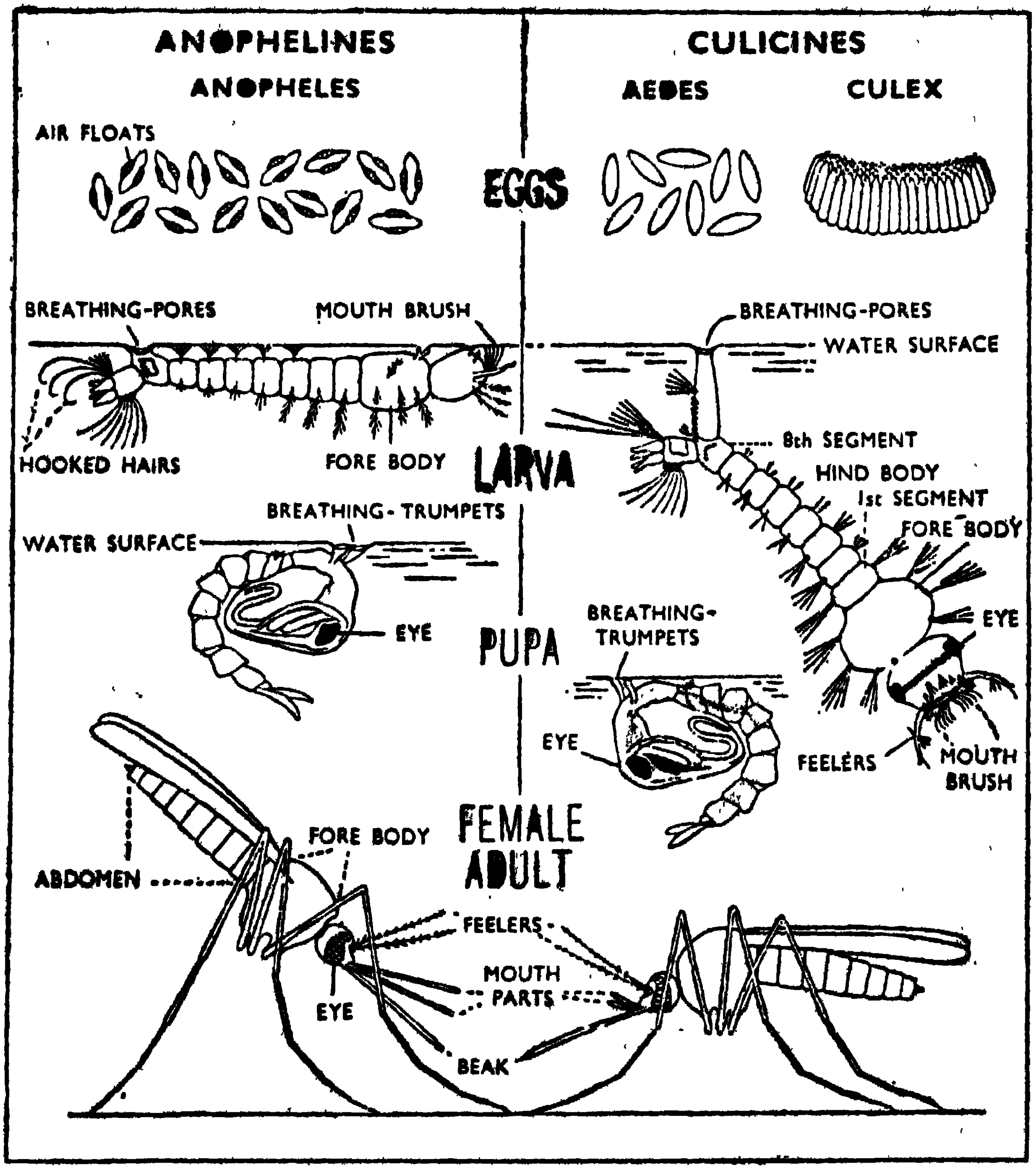


FIG. 67.—The life history of the mosquito

blood). The *female* mosquito, however, besides having a sucking tube for plant juices, also has a set of six needle-like mouth parts inside the 'beak', which are used to pierce the skin and suck the blood of *animals*—including human beings (see Fig. 68). Only the female mosquito sucks blood.

The *fore-body* bears *three pairs of jointed legs*, and *one pair of wings* together with a pair of tiny '*balancers*'. (The legs are used mainly for *resting* and not for movement, as a mosquito usually flies from place to place.)

The *hind-body* consists of ten segments, of which only eight can be readily distinguished.

Life history of mosquito

The *female Anopheles* lays anything up to 300 eggs, one by one, on a water surface. Each egg is shaped rather like a boat, and has a small *float* on either side which helps to keep the egg on the surface of the water (see Fig. 67).

About forty-eight hours later, the egg hatches out into a *larva* (see Fig. 67) with a distinct head, fore-body, and hind-body. In its early stages the young larva absorbs dissolved oxygen from the water and feeds on suspended food-particles, growing rapidly. About twenty-four hours after

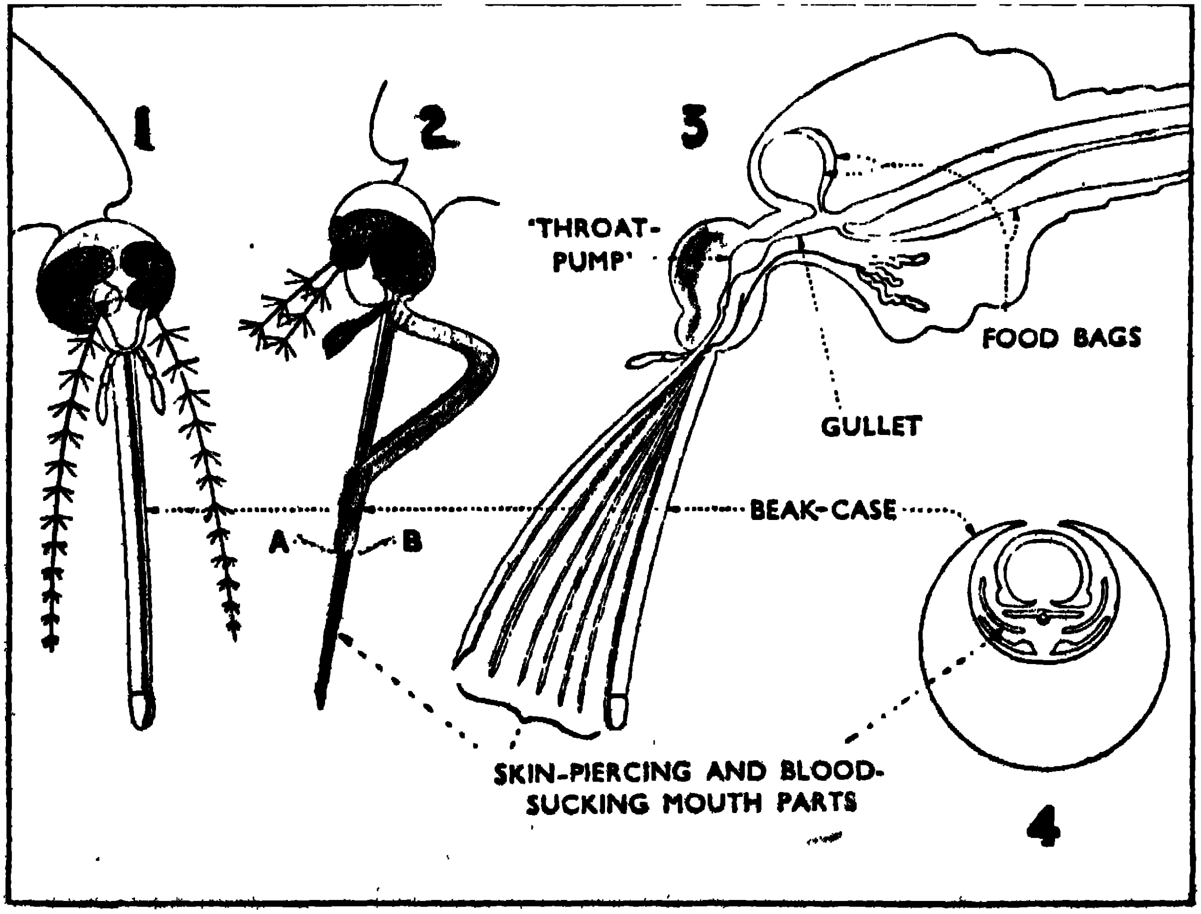


FIG. 68.—Mouth parts of female mosquito

showing the beak (1) at rest, (2) during the act of biting, (3) with the mouth parts separated, and (4) in cross-section. (In 2, the dotted line A-B indicates the surface of the victim's skin.)

hatching, the young larva casts its skin. It repeats this process of feeding, growing, and skin-casting four times. During the later stages, the anopheline larva breathes air through a pair of *breathing pores* on the eighth segment of the hind-body, lying in a horizontal position below the surface film while breathing, and feeding with its mouth-brush.

After the fourth skin-casting and between one and two weeks after hatching, the larva becomes a comma-shaped *pupa*, with a large head and fore-body (see Fig. 67). This is a *resting stage* during which the legs, wings, feelers, and mouth parts of the adult insect are developing. The pupa does not feed; but it rests tail downwards beneath the surface film, breathing air through a pair of cone-shaped *breathing trumpets*, which project from the head end.

After a couple of days as a pupa, the adult insect emerges. The insect rests on the surface of the water for an hour or two while its wings expand and harden, and the adult mosquito then flies away. Mating takes place soon afterwards.

The adult *Anopheles* rests in a sloping position, head downwards, so that its body and beak are in one straight line, making an angle of 30°–40° with the resting surface (see Fig. 67). (*Culex* rests with its body parallel to the resting surface.)

MALARIA

Until quite recent years, malaria was considered to be the most widespread disease in the world, and besides causing millions of deaths every year directly and indirectly, it was also the chief obstacle to progress and development because millions of people were so weakened by malaria that they could not live happy and useful lives. Recent discoveries, however, have greatly reduced the threat of malaria to mankind and ultimate victory over the disease is now in sight. Malaria has already been completely rooted out from several communities where sufficient funds and organizing ability were available for this purpose.

The story of malaria forms such an important example of Man's conquest of disease that we must outline it here.

Malaria is known to have been one of the most serious human diseases for over 2,000 years, but nothing was known of how it was caused or how it could be controlled until more recent times. The first step towards the *control* of malaria was made in the seventeenth century, when it was found that an extract of *cinchona bark* (which contains *quinine*) could *cure* the disease. But nothing was known of its *cause* until as recently as 1880, when the French colonial doctor Laveran discovered the *malaria parasite* in the red blood-cells of one of his malaria patients. During the next few years Italian doctors traced nearly all the stages through which the parasite passes in human blood, but *how the parasite entered the blood* was still unknown. About 1895, Manson (the British doctor who had discovered that the *Filaria* parasite was carried from man to man by mosquitoes) suggested to Ross (a British army doctor in India) that malaria might be carried in the same way, and Ross soon found the parasites of *bird-malaria* in the stomach wall of a female mosquito which had sucked blood from an infected bird. In 1896, Ross discovered how the parasites that cause bird-malaria pass from the mosquito's stomach into its salivary glands, ready to enter the next bird bitten by the infected mosquito. This completed the life-history of the malaria parasite in birds and suggested that human malaria might be transmitted in the same way by mosquitoes. The work of Ross was soon followed up in Italy, where two Italian doctors proved that human malaria was transmitted by mosquitoes, and it became clear, at last, that if there were no mosquitoes there would be no malaria.

This discovery that mosquitoes carried disease was soon applied to *mosquito-control*, e.g. in Central America, where de Lesseps (who made the Suez Canal) had been compelled to give up work on the Panama Canal, in 1881, because of disease among the workers. The Americans afterwards re-opened and completed the scheme with the aid of mosquito-control.

The next forward step was the discovery that only *Anopheles mosquitoes* carry human malaria and that only a few species of anophelines are of practical importance. This greatly simplified the problem of mosquito-control, because each species of malaria mosquito favours a special type of breeding-place and has its own particular feeding-habits.

Life-history of malaria parasite

Although both male and female anophelines feed on plant-juices, the female *Anopheles* has to suck blood if her fertilized eggs are to develop, and as she digests the blood, her eggs develop. To obtain this blood, the beak and its needle-like mouth parts are forced through the victim's skin. Liquid from the insect's *salivary glands* is then squirted into the wound to stop the blood from clotting and to break up the red blood-cells, which are too large to pass through the insect's beak. Then the blood is sucked up and passed into the insect's 'stomach'. If the victim is suffering from *malaria*, his blood contains microscopic, one-celled *malaria parasites*

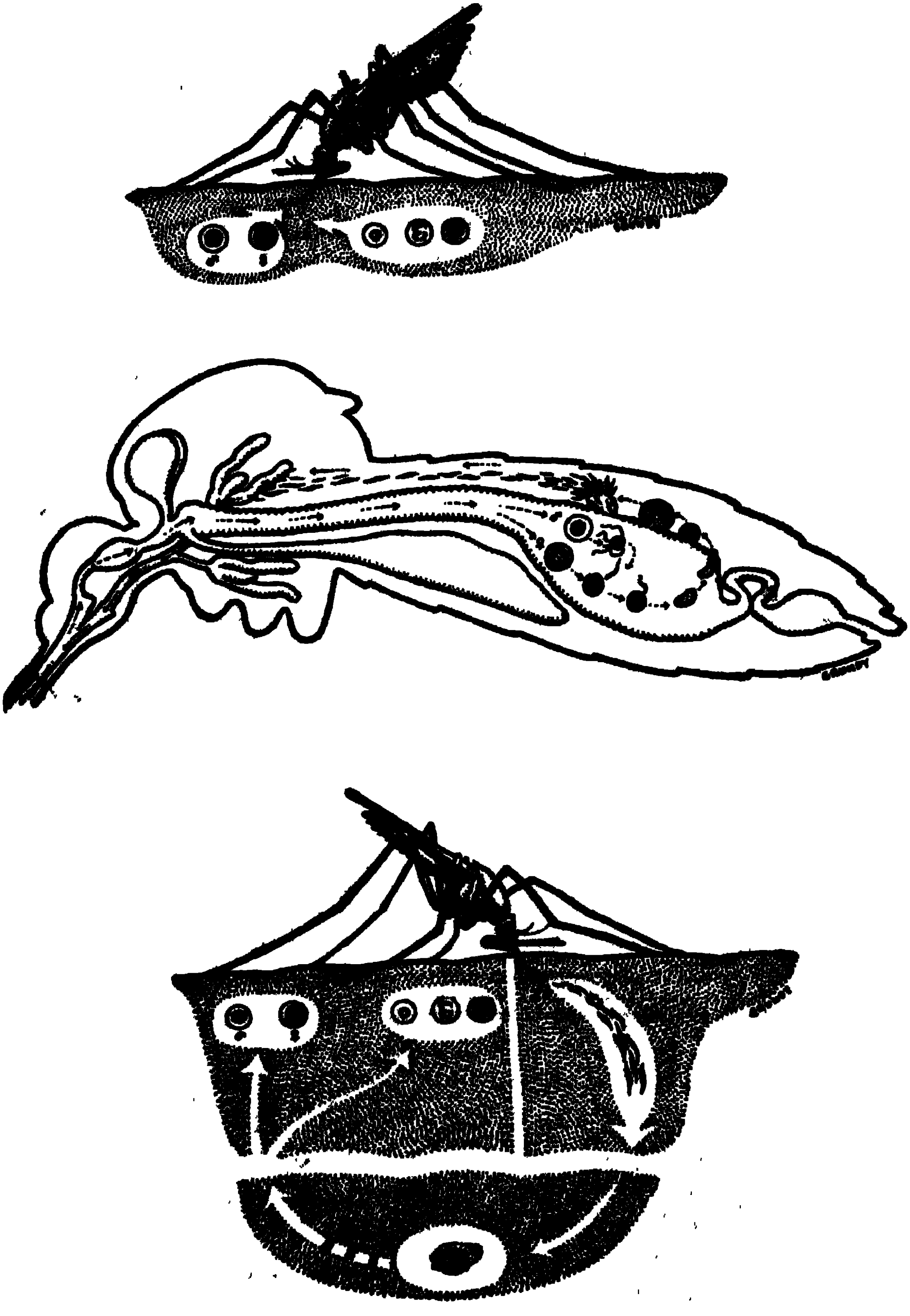


FIG. 69.—The malaria cycle

Diagrammatic. The sizes of the parasites and mosquitoes are not in proportion to each other. For explanation, see foot of opposite page.

(Fig. 69) and some of these are sucked up with the blood and enter the insect's 'stomach' (see Fig. 69). Here, a number of changes take place, and very small, needle-shaped parasites are produced, which make their way to the insect's salivary glands (see Fig. 69). Then, nine to twelve days after the mosquito bit the infected patient, if the insect bites another person, some of these malaria parasites are injected into his blood-stream (see Fig. 69). These newly-injected parasites soon make their way from the blood-stream into the liver-cells, where they develop for about a week before returning to the blood-stream and entering red blood-cells. In the red blood-cells each parasite grows and divides into many more, and after forty-eight hours (in 'benign tertian malaria') the infected red blood-cell bursts, setting free the parasites into the blood-stream. Some of the parasites succeed in entering other red blood-cells, and this is repeated every forty-eight hours. In this way the parasites multiply until, about 10–14 days after infection, there are millions of parasites in the blood and the first outward signs of the disease appear. There are about one million parasites per c.c. of blood when these signs develop. The signs of the disease usually appear in three stages: (i) the *cold stage*, (ii) the *hot stage*, and (iii) the *sweating stage*. The patient first feels cold (although his temperature has begun to rise); then, an hour or two later, his skin feels hot and burning, and his temperature rises still further. Then, after a few hours of severe discomfort and headache, the patient begins to sweat and his temperature falls rapidly until, a few hours later, the patient feels quite comfortable, although tired and worn-out. The attack of fever takes place when the infected red blood-cells burst, setting free parasites along with some poisonous substance. Since (in tertian malaria) this course of events is repeated every forty-eight hours, there is an attack of fever every other day. (*N.B.* In the *first* attack of malaria, the fever is usually continuous for the first few days.) What has been described above is a simple, straightforward attack of *benign tertian malaria*, but unfortunately there are more

The top diagram shows a female *Anopheles* feeding on a man with malaria and taking in blood containing both male (♂) and female (♀) malaria parasites.

The centre diagram shows how these male and female malaria parasites unite in the mosquito's 'stomach' to produce a single egg-like body which develops in the wall of the 'stomach', producing large numbers of small, needle-shaped parasites which make their way to the insect's salivary glands. This stage of development of the parasite inside the mosquito takes at least a week.

The bottom diagram shows the same mosquito feeding again on a man after the above stage of development is complete. She is injecting the needle-shaped parasites into the human skin, and within half an hour they will make their way to the liver where they develop for another week before returning to the blood-stream and entering red blood-cells.

dangerous forms, and malaria should therefore be treated by a doctor—it is not a disease to regard lightly.

After a time, some of the parasites change into larger organisms of a different type which do not produce fever, and if the patient is bitten by a female *Anopheles* at this stage (i.e. from seven to ten days after the attack of malaria began) these parasites are sucked up with the blood and pass into the insect's 'stomach' (see Fig. 69).

The life-history of the benign tertian malaria parasite, therefore, is very complicated and occupies about thirty days, consisting of two distinct stages, (i) in the human body (twenty-one to twenty-four days), and (ii) in the mosquito's body (nine to twelve days). You will notice that in order to pass on the malaria parasite, a female *Anopheles* must seek a second blood-meal nine to twelve days after picking up parasites at her first blood-meal.

There are four different species of malaria parasite affecting man, producing four different kinds of malaria, the following three species being the most important: (i) *Plasmodium vivax* is the one-celled, microscopic parasite that causes *benign tertian malaria* with attacks of fever about every forty-eight hours. It was called *benign* malaria because this disease seldom kills the patient. (ii) *Plasmodium falciparum* is the germ of *malignant tertian* (or *sub-tertian*) *malaria*. The attacks of fever recur about every forty-eight hours (as with benign tertian) and this disease is more often fatal. (iii) *Plasmodium malariae* produces *quartan malaria*, a relatively mild disease with the fever recurring about every seventy-two hours. As these different types of malaria require different curative treatments it is particularly important that expert medical advice should be sought early in all cases of recurrent fever.

The prevention of malaria

The old saying 'Prevention is better than cure' is even truer of malaria than of any other disease, because although it is possible to cut short an attack of the disease, it is extremely difficult to remove all the malaria parasites from the patient's body. In principle, there are three different ways of rooting out malaria: (i) *destroy all malaria-carrying mosquitoes*, or (ii) *protect everybody from mosquito bites*, or (iii) *destroy all malaria parasites in human beings*. Malaria has been controlled in the past by making use of all three methods, but now that new *insecticides* are available which are very deadly to mosquitoes, the first method has become the most effective.

MOSQUITO CONTROL

Before the discovery of these new insecticides (e.g. DDT) the best way of freeing a district of mosquitoes was to prevent them from breeding. Since the early stages of the life-history are spent in water (see p. 166), the first step is to see that any suitable collections of water are removed or made unsuitable. Small pools should be filled in and vessels such as old tins, jars, bottles, and coconut shells should be cleared away. Rain-water roof-channels and pipes should not be allowed to bend and hold water, and holes in decaying trees should be filled up with cement. Any open drains for carrying off surface-water should have smooth, sloping sides and should be kept clean so as to give no hold to larvae and to carry off the rain-water as rapidly as possible. Better still are *subsoil drains* of unglazed earthenware pipes laid below the surface so that the excess water is carried off underground, out of reach of mosquitoes. (This method is widely used for draining narrow valleys.) Pools which cannot be filled in or drained should be treated with oil. If a thin layer of oil is spread on the surface of the water, the mosquito larvae and pupae cannot breathe, and therefore die. If DDT is added to the oil, then the mosquito larvae are poisoned. Since it takes more than a week for an egg to develop into an adult mosquito, if oil is properly applied at seven-day intervals, breeding is impossible.

In recent years, *permanent control* of anopheline mosquitoes has been carried out over large areas by the use of DDT and similar insecticides, and these new substances have now completely revolutionized anti-malarial work so that it is becoming possible to make a general attack on malaria throughout the tropics. DDT is very deadly to mosquitoes and other insects, and if walls and ceilings of houses are sprayed with a solution or suspension of DDT, after the liquid evaporates tiny crystals of DDT are left behind. When a mosquito rests on the wall and its feet touch the DDT it absorbs a poisonous dose and dies in a few hours. DDT is also used mixed with oil for spraying mosquito breeding-places. In the island of Cyprus, for example, anopheline mosquitoes have been completely wiped out by treating all their breeding-places with DDT. In British Guiana, two of the most dangerous species of anopheline mosquitoes have been wiped out by spraying the inside of every building with insecticide, and malaria has practically disappeared from these areas, which include rice fields and sugar-cane fields, swamps and waterways. This success is being repeated in the island of Mauritius. In Southern Rhodesia, four teams of fifteen men, in one season, almost stamped out malaria over an area of nearly 2,000 square miles by spraying every building with DDT. On farms in this area it was customary for 20–25 per cent. of the labour force to be ill at any one time throughout the wet season. After every hut had been sprayed with DDT every farm was working at practically full strength. Similar results have been achieved in the Transvaal, in parts of Brazil, in Bombay Province, in Italy, Greece, Venezuela, and the U.S.A. So a disease which has been one of Man's worst enemies for over 2,000 years is at last being conquered.

Protection against mosquito-bites

In areas where anopheline mosquitoes still exist, an important means of preventing the spread of malaria is to *protect people from mosquito-bites.* In some very malarious districts, doors, windows, and other openings in houses are covered with fine wire-gauze to keep out mosquitoes. This is rather costly (and it also interferes with free ventilation), hence sometimes

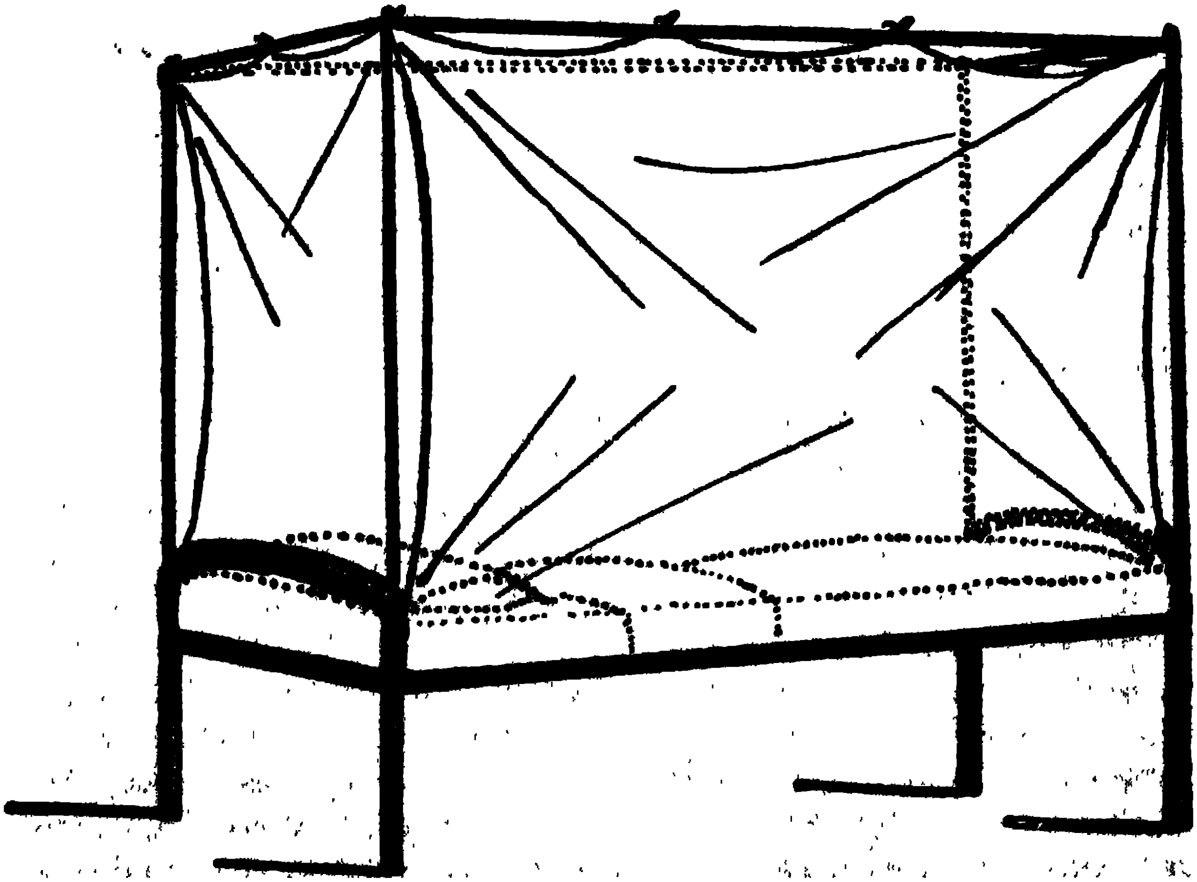


FIG. 70.—Bed, with mosquito-net tied inside the frame and tucked under the mattress

only a single room is made mosquito-proof, for use after sunset. In any case, everybody living in a district where malaria exists should sleep under a mosquito-net. The net should be put down before sunset and its edges should be pushed under the bed (see Fig. 70). Long trousers and long sleeves should be worn after sunset in malarious areas.

Most important of all, *any patient suffering from malaria* (*or getting better from an attack*) *should stay in a mosquito-proof room or under a mosquito-net*, so as not to infect mosquitoes which may later spread the disease. The greatest care is necessary between sunset and sunrise, when malaria-carrying mosquitoes are most active.

Destruction of malaria parasites

In theory, if every human being infected with malaria could receive proper treatment in the early stages of the disease, malaria could be completely wiped out. In practice, however, this ideal has not been realized and the destruction of anophelines by the use of insecticides is a much more promising method for stamping out malaria. But the use of drugs is still necessary under special conditions, e.g. in dealing with sudden outbreaks of malaria. *Quinine* will destroy the malaria parasites in the blood, *but only at certain stages* of the life-history. Quinine has no effect on the fine, needle-like parasites injected by the biting insect. Neither has it any action on the larger form of parasite which is produced in the blood as the patient is recovering and which can infect the biting mosquito. Quinine will kill the parasites when inside the red blood-cells or when they have been set free into the blood-stream. *Mepacrine* (*Atebrin*, *Quinacrine*) also kills the parasites in this fever-producing stage, but it is much more active than quinine. In fact it is possible, when exposed to the bites of infected mosquitoes, to *prevent* an attack of malaria by taking sufficient Mepacrine. *Pamaquin* (*Plasmoquine*) destroys the larger type of parasite which is sucked up by the mosquito, and thus prevents the human patient from infecting the mosquitoes that suck his blood when he is recovering from an attack of fever. That is, the use of Pamaquin benefits the community. *Paludrine* is a very valuable drug both for preventing and curing malaria. No previous anti-malarial drug had any effect on the malaria parasite at the stage when it is developing inside the liver-cells and before it enters a red blood-cell. This is a great advance, for if a small dose of Paludrine is taken at regular intervals it is possible to prevent development of the parasites before they can produce fever. The proper use of Paludrine, therefore, will keep people free from malaria even when they are exposed to infection in malarious areas. Another drug used for treating malaria is *Chloroquine*.

YELLOW FEVER

In the eighteenth and nineteenth centuries, *yellow fever* was very common in tropical and sub-tropical countries bordering on the Atlantic Ocean, and the disease was much more deadly than malaria. Today, yellow fever is limited to a few small areas in Central and South America and in Africa south of the Sahara. Since yellow fever is so seldom met with, it may seem a waste of time to discuss a disease which is unknown in most countries, but we shall see that there is a serious danger that the disease might be introduced, with terrible results. Yellow fever, like malaria, is passed on by mosquitoes. There are two forms of yellow fever: (*a*) *urban yellow fever*, which affects only Man, and (*b*) *jungle yellow fever*, which is a disease of monkeys sometimes spreading to Man. The two different forms of the disease are transmitted by two different kinds of mosquitoes.

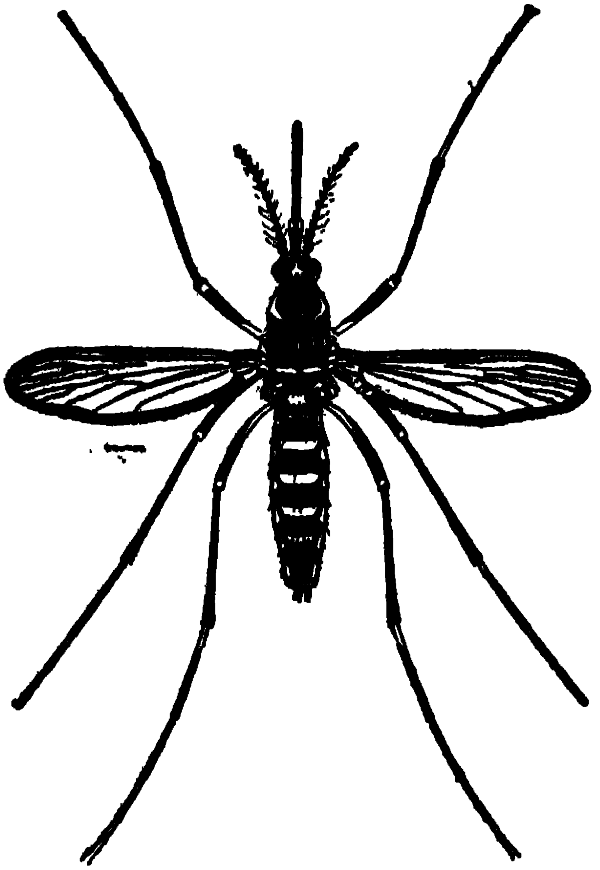


FIG. 71.—*Aëdes aegypti* mosquito (female) (magnified 7 times)

Note the characteristic markings of body and legs, the short palps flanking the proboscis, and the antennae bearing a few hairs

(This mosquito carries yellow fever and dengue)

The carrier of *urban yellow fever* is the very common 'tiger mosquito' (its scientific name is *Aëdes* or *Stegomyia*) (see Fig. 71). This mosquito is easily recognized because its legs and body bear white stripes. *Aëdes* breeds usually in clean water standing in old tins, jars, bottles, roof-channels, and water-tanks, while anopheline mosquitoes breed in more natural deposits of water. Hence the 'tiger mosquito' is mainly a town and house mosquito, while *Anopheles* is commoner in country districts. The germ of yellow fever is a very small *virus*. When a tiger mosquito bites a yellow fever patient during the first three days of the fever, it sucks up some of the virus, and about a week later the mosquito becomes infectious for Man and remains infectious for the rest of its life. If an infected tiger mosquito bites a man, the yellow fever virus is introduced into his blood, along with the insect's saliva. Between three and six days later, the patient has a sudden attack of fever, lasting three or four days, which is rather like *dengue*. In severe cases the skin and the whites of the eyes become yellow and bleeding within the body occurs. In many cases the patient dies. If the patient recovers, he is immune for life.

Jungle yellow fever is spread among jungle monkeys in South America and in East and West Africa by other kinds of mosquitoes which breed only in thick jungle, away from most human settlements, but which spend their lives among the tree-tops (where the monkeys also spend most of their lives). A man occasionally becomes infected while in the jungle and returns to his village or town before the disease develops. If, during the first few days of his fever, he is bitten by *Aëdes* mosquitoes, this single case of jungle yellow fever may give rise to an epidemic of yellow fever, for the same virus causes both forms of the disease.

It is now possible to protect people from yellow fever by vaccination with small quantities of a mild type of yellow fever virus obtained originally from the blood of a West African who recovered from an attack of yellow fever in 1927. This special virus is cultivated inside hens' eggs, from which the vaccine is prepared, dried, and frozen for storage until required for use.

Although yellow fever is unknown in Asia, there is no reason why it should not spread rapidly if the infection were once introduced: the carrier is one of the commonest mosquitoes. In the past, the length of the voyage from infected countries has stopped the spread of the disease, for an infected passenger who developed the disease would become non-infectious long before reaching a non-infected country. Today, however, owing to the introduction of rapid travel by air, there is a serious danger that a passenger might be bitten and infected just before leaving West Africa, for example, and then become infectious some seven to ten days later, when he had arrived at a country free from yellow fever but having plenty of tiger mosquitoes. To prevent the spread of yellow fever in this way, all countries have agreed to spray the inside of aircraft with insecticide just before leaving one country and immediately on arrival in another, to keep airfields free from mosquitoes, and to see that all passengers leaving a yellow fever country have been vaccinated against the disease.

FILARIA-WORMS

The commonest of the parasitic filarial blood-worms is carried mainly by female *Culex* mosquitoes which have sucked blood from an infected person (see Fig. 72). The young filaria-worms carried by the mosquito are about 1·5 mm. long, and when the mosquito bites a human being the young filaria-worms enter the skin near the bite and make their way to the lymph-vessels. When fully grown (about 10 cm. in length) these filaria-worms may block some of the lymph-vessels, sometimes causing huge swellings, particularly of the legs and feet, called *elephantiasis*. An adult female filaria-worm produces vast numbers of small, thread-like embryo worms (about 0·3 mm. long), which enter the blood-stream. These tiny creatures live in the larger arteries during the day, but towards evening they travel to the capillary blood-vessels under the skin, remaining there until next morning. If a female *Culex* mosquito bites a filaria patient at night, therefore, and sucks blood, it becomes infected with the micro-filaria-worms, which make their way from the mosquito's stomach into the muscles of its fore-body, where they grow to a length of about 1·5 mm. and then enter the mosquito's head, coiling up near the base of its 'beak', ready to enter the skin when the mosquito bites a human victim.

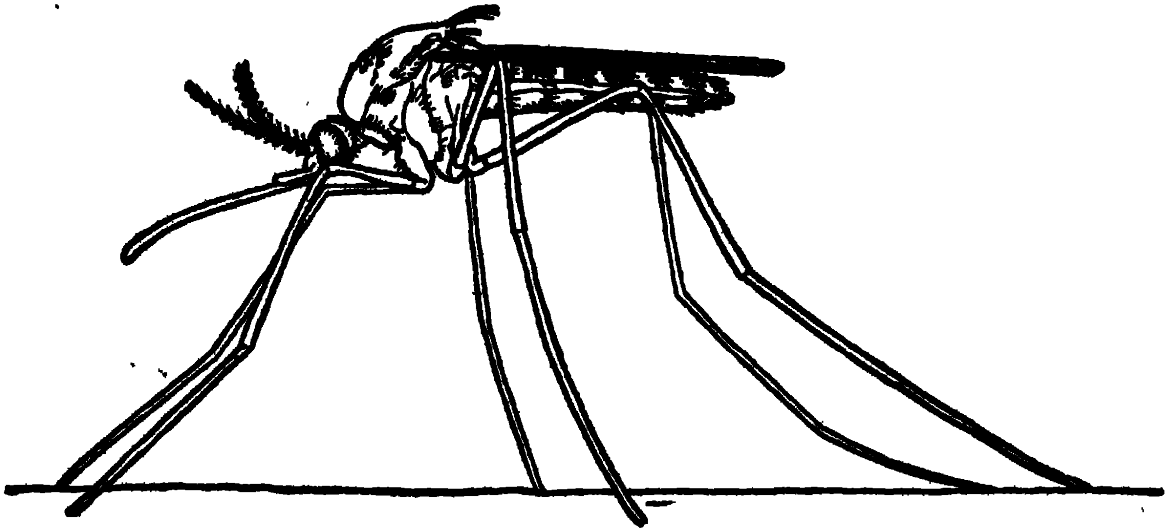


FIG. 72.—*Culex* mosquito (female) resting position (body parallel to the surface) (magnified 10 times)

(*Aëdes* adopts a similar position)

Since it is very difficult to get rid of the parasite from an infected human patient by direct treatment, the prevention of infection is very important.

The chief means of prevention are *mosquito control* and *protection from mosquito-bites* by sleeping under a mosquito-net. It is particularly important that anyone infected with filaria-worms should sleep under a net.

Another filaria-worm, *Loa loa*, is common in West and Central Africa, and is carried by mangrove flies. *Loa loa* causes 'Calabar swellings' under the skin. These do not last long and are relatively harmless, but the worm sometimes causes more serious trouble by making its way into the *conjunctiva* (the thin outer membrane covering the front of the eyeball and inner eyelid).

Another filaria-worm, *Onchocerca*, is found in Man in Equatorial Africa and in Central America, being carried by biting flies. Like *Loa loa*, these worms cause swellings under the skin and may also invade the eye, disturbing the eyesight and sometimes even causing *filarial blindness*. As with *Loa loa*, protection from infection by controlling the carrier-flies is difficult.

The Guinea Worm (see Fig. 33) is the largest of the filaria-worms and is not carried by insects but by water-fleas which may be swallowed when drinking unboiled water drawn from an unprotected well.

DENGUE AND SAND-FLY FEVERS

The tiger mosquito can also carry the virus of another fever—*dengue*. *Sand-fly fever*—another disease carried by *sand-flies* and not mosquitoes—is so similar to dengue that it is often impossible to distinguish between the two; but this does not matter much, as the treatment is the same for both. Although neither of these fevers is very dangerous, and patients seldom die, the early stages are like those of yellow fever. If a tiger mosquito bites a dengue patient during the first three days of his fever, it sucks up some of the virus along with the blood. The mosquito becomes infective about ten days later, and remains infective for the rest of its life. If the infected mosquito bites a healthy person, the virus is introduced into his blood. Four to nine days later, he may suddenly have an attack of fever with severe pains in the back and limbs. (Hence dengue is sometimes called 'break-bone fever'.) The fever lasts for three or four days and then disappears for a day or two. Then there is a short return of fever, and measles-like spots appear on the skin. Dengue has to run its course; the patient should go to bed as soon as he feels ill, and stay there for seven to ten days until he feels quite well again.

The best way to control dengue is by the destruction of tiger mosquitoes and the use of mosquito-nets by everybody. Any district with a lot of tiger mosquitoes may have frequent epidemics of dengue.

Sand-flies are small enough to pass through an ordinary mosquito-net, hence in places where sand-fly fever and other diseases carried by sand-flies are common (see below), it may be necessary to use bed-nets of finer mesh. But sand-fly nets restrict air-movement so much that it is uncomfortably hot inside such a net. Sand-flies, however, usually remain near the ground, so they are less troublesome in upstairs bedrooms, especially where there is free air-movement to blow these tiny flies away from sleeping people. Spraying the ground around houses with DDT helps to reduce the number of sand-flies.

KALA AZAR

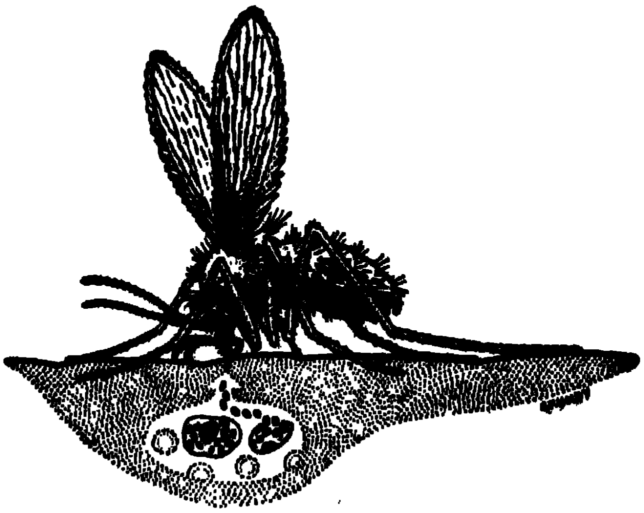
Sand-flies also carry the microscopic one-celled organisms *Leishmania* that cause *kala azar*, *oriental sore*, and *espundia*, three closely-related diseases (see Fig. 73). *Kala azar*, found in Africa, China, India, and South America, is a slow, wasting disease accompanied by fever. It is nearly always fatal if not treated by injecting suitable drugs. In a malarious country only a doctor can decide whether the patient has malaria or kala azar.

Oriental sore, found in Africa, India, and the Middle East, is a skin sore that develops slowly in exposed parts of the body, usually on the face, arms, and legs. Oriental sore usually cures itself, after many months, and the patient is then immune to further attacks, but the sore can be cured more quickly by injections of drugs.

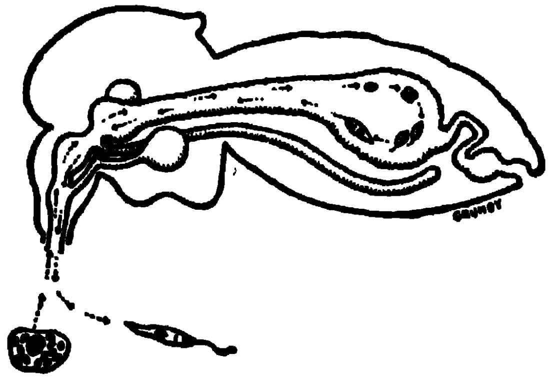
In cases of *espundia* (found chiefly in South America, but also in the Sudan) the sores attack the nose and mouth, destroying large amounts of tissue, and the disease, if left untreated, is often fatal. Treatment is by injecting drugs similar to those used for kala azar, but espundia is a difficult disease to cure.

PLAGUE

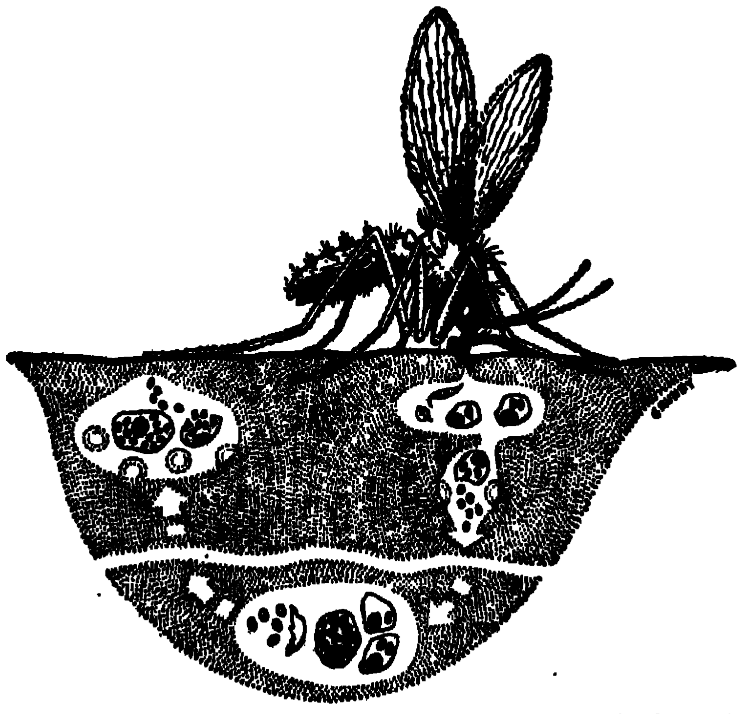
Plague is another disease carried by a blood-sucking insect—the *rat-flea*. Plague is primarily a disease of rats and other rodents, caused by *plague bacteria*, but it may be carried by fleas to Man and several other mammals. When a rat is suffering from a severe form of plague, the germs of the disease are present in the blood. If a flea bites this rat, it sucks up blood containing plague bacteria. The plague bacteria then multiply so rapidly



The sand-fly takes up the leishmaniae (round forms), when it bites a patient (or dog) suffering from leishmaniasis



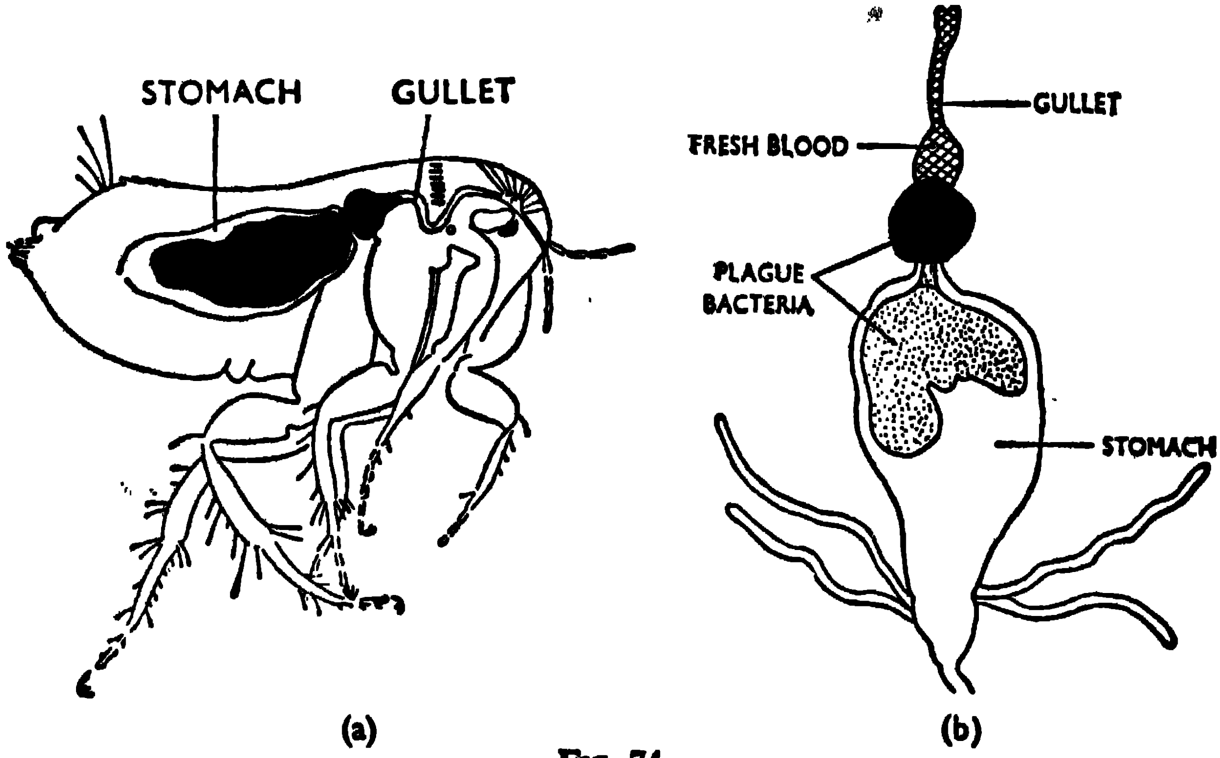
The leishmaniae develop and increase in numbers by a process of division in the stomach of the sand-fly. They become elongated and move forward to the pharynx, and there multiply so greatly that tney block the passage



The sand-fly injects the elongated, free-swimming forms into man (or dogs) when it subsequently attempts to feed. The whole cycle in the sand-fly occupies about 10 days

FIG. 73.—The leishmaniasis cycle

in the insect's food-canal that a semi-solid mass is formed, blocking up the stomach and gullet (see Fig. 74). When the rat dies (usually a few days after being infected) the infected flea leaves the dead body as it cools, and looks for another victim, preferably another rat; but if the flea fails to find another rat it may bite a human being and attempt to suck blood. But as its 'stomach' and gullet are blocked, instead of sucking blood it forces out some of the contents of its gullet into the bite, thus introducing plague bacteria into the victim's tissues. The bacteria multiply and spread through the neighbouring lymph-vessels and may also enter the blood, and, about three days after infection, the outward signs of the disease appear.



(a) (b)

FIG. 74.

(*a*) Rat-flea with 'stomach' blocked with mass of clotted blood and plague bacteria
(*b*) Rat-flea's 'stomach' and gullet blocked with clotted blood and plague bacteria

About three days after infection there are a sudden rise of temperature, severe headache, and pains in the back. The nervous system is disturbed, and the patient seems to be intoxicated. About the same time, in most cases, the lymph-glands at the top of the thigh or under the armpit become swollen and tender. The swelling is called a *bubo*, and this type of plague is called *bubonic plague* (or *lymph-gland plague*). Most victims of plague soon die unless treated with recently-discovered drugs.

In some rare cases, buboes do not develop and the plague bacteria multiply in the blood-stream rather than in the lymph-vessels, causing an even more deadly type of plague (*septicaemic plague* or *plague blood-poisoning*). It is from victims in this stage of the disease that fleas may become infected when they suck blood.

In still rarer cases, the patient's lungs become infected with plague bacteria, and this type of plague (*pneumonic plague*) is extremely infectious, being spread by droplet infection. It is so deadly that the patients nearly always die within a few days.

Since treatment does not always cure plague, prevention becomes most important. Rodent-plague always exists before human plague breaks out, hence it is important to destroy as many rats (and their fleas) as possible by trapping, gassing, and poisoning (and fleas by the use of DDT). Buildings, especially in sea-ports, should be made rat-proof. Whenever unusually large numbers of dead rats are found anywhere, a report should be made to the public health authorities, who will collect the rats (with great care) and have them examined in a laboratory. Rats must be stopped from coming ashore from ships in port, and there must be strict quarantine of trains, ships, aeroplanes, and their passengers arriving from plague-infected countries. Anti-plague inoculation gives considerable protection from infection.

TYPHUS

There are several kinds of fever caused by *rickettsiae* (micro-organisms smaller than bacteria but larger than viruses), all of which are carried by blood-sucking insects, mites, or ticks. The four chief diseases in this group are (i) *mite-borne typhus*, (ii) *tick-borne typhus*, (iii) *flea-borne typhus*, (iv) *louse-borne typhus*.

Mite-borne typhus, also known as *scrub-typhus*, *Japanese river fever*, and *tsutsugamushi disease*, is believed to have spread from the banks of certain rivers in the main island of Japan through many parts of the Far East, e.g. Burma, Malaya, and New Guinea. It is a disease of rats and field-mice, carried to Man by the bite of the larva of a tiny *mite* (see Fig. 75). The germs of the disease are present in infected

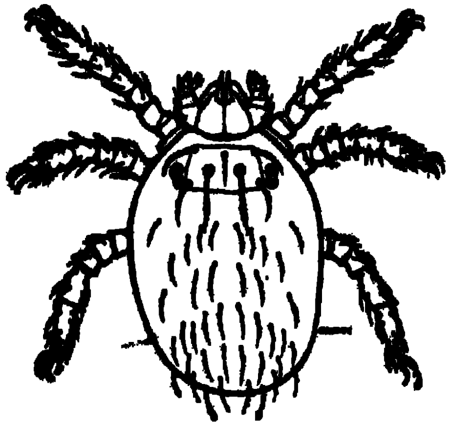


FIG. 75.—Larval mite of the kind which carries scrub typhus (magnified 60 times)

field-mice or rats, and the larval mite (about 1 mm. long) becomes infected when it bites infected mice or rats. The rickettsiae are passed on to the larva of the mite, and this larva (about 0·2 mm. long) can infect human beings. Men walking through grass where infected rats and mice exist may be bitten by the infected larva of this second generation. Scrub-typhus is commonest in rat-infested land that once was cultivated but which has become overgrown with scrub. The first signs of the disease appear from five to fourteen days after infection, when the fever begins, reaching dangerously high temperatures after a few days and often continuing for two or three weeks if the patient does not die earlier.

Until very recently no drug was known to cure this deadly disease, but newly discovered drugs are giving very successful results, and, where the new treatment is available, scrub-typhus is no longer such a highly dangerous disease.

To avoid infection, all parts of the body should be covered when walking through infected areas, and a bath should be taken as soon as possible afterwards. An additional precaution is to treat the clothing with certain chemicals which repel or kill the mite larvae. If the tiny, reddish larval mite is discovered on the skin, it should be removed at once and the bite disinfected.

Tick-borne typhus is a disease of rats, mice, and dogs and is found in South, West, and North Africa, southern Europe, North and South America. It is carried by ticks parasitic on these animals and if one of these infected ticks bites a man, he becomes infected. The course of the disease is very similar to that of mite-borne typhus and the new drugs give equally encouraging results.

Flea-borne typhus is a disease of rats, carried from rat to rat by rat-fleas. Infected fleas sometimes bite Man if they cannot find a rat. This is a less common disease than the other forms of typhus and seldom produces an epidemic among human beings.

Louse-borne typhus is carried from man to man by body-lice and is therefore commonest in lousy and crowded communities, especially under cold conditions, where bathing and the changing and washing of clothes are difficult or impossible. In the tropics, where it is usually easy to bathe and to wash one's clothing, louse-borne typhus is less common than the other forms. With the discovery of new and powerful insecticides like DDT it is now possible to kill body-lice very easily, simply by blowing DDT powder up the sleeves and trouser-legs and down the collar of lousy people without even undressing them. This kills all their body-lice and prevents them becoming lousy again for several weeks even though they do not change their clothes. This method has been used with great success among refugees in time of war or famine and under cold conditions. Although DDT kills lice, it does not kill the *rickettsiae* in the dried louse faeces, hence clothing from a louse-borne typhus patient must be removed with great care (by someone wearing a pad over mouth and nose) and then boiled or, better, burned, because the disease can be caught by breathing dried infected louse faeces.

LEPTOSPIROSIS

Although this disease is not carried by insects, it is convenient to discuss it here since it is also a disease of rats. The disease is caused by invasion of the blood-stream by a microscopic, one-celled organism called *Leptospira* (hence the disease is sometimes called *leptospirosis*). The germ may enter the body if water containing the urine or faeces of infected rats is swallowed. Infection may also enter through the skin by contact with damp soil in places where there are rats. Swimming in infected pools and rivers is a common cause of infection, since if the germs are in the water they may either be swallowed or enter the body through the skin. Besides this, the damp earth on the bank may be infected, and germs may enter through the bare feet, especially if the skin is broken.

From five to twelve days after infection, there is sudden fever with shivering, headache, vomiting, and frequent watery motions.

The eyes become bloodshot, and after two or three days the skin becomes yellow and the urine strongly coloured. The disease is often fatal, and a doctor should be called in during the early stages.

To avoid infection, one must be very careful about swimming in pools and streams. Public baths, too, should be rat-proof and the water should be properly filtered and disinfected. Food should be carefully protected from contact with rats. Destruction of rats helps to control the disease.

BILHARZIA DISEASE

The *Schistosomes* (or *Bilharzia*) are parasitic worms causing human disease. They are not transmitted by blood-sucking insects but are considered here because they invade the blood-stream. In some parts of Africa, no less than 50 per cent. of the population are infected with these schistosomes. The parasite is a small worm, or *fluke*, which lives in the veins, mainly in the portal vein near the bladder and rectum. The male fluke is shaped like a leaf, about half an inch in length, and rolls up to form a channel in which the female fluke lives, laying her eggs in the victim's portal vein. These eggs are oval in shape, with a sharp point at one end, and they bore their way through the walls of the bladder and rectum, causing irritation and bleeding (see Fig. 76). The eggs burst as soon as they reach water, setting free tiny embryos which swim about searching for their intermediate host, a fresh-water snail (see Fig. 77). If an embryo finds a snail, it bores its way into the snail's liver, where it undergoes a series of changes, finally producing a number of microscopic, tadpole-shaped animals which escape into the surrounding water, where they swim about looking for their other host—Man. If they do not find a human host within thirty-six hours after leaving the snail, they die. If they find a man, they bore through his skin, causing severe itching, make their way to the portal vein, and develop into adult blood-flukes after a few weeks, thus completing the life-cycle. A doctor can cure bilharziasis by injecting a drug. Infection can be prevented

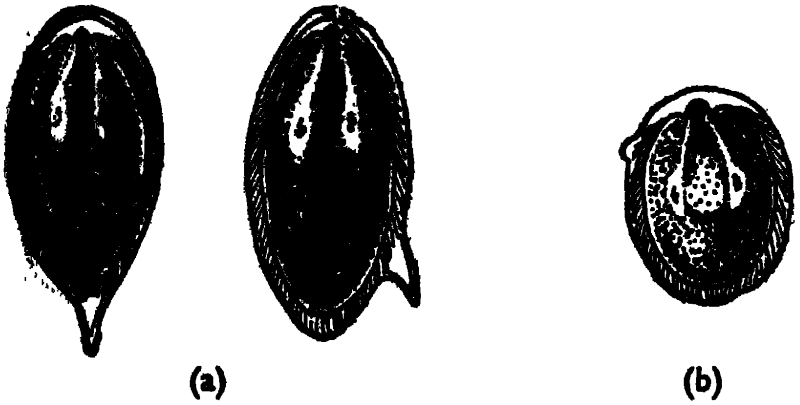


FIG. 76.—Eggs of schistosomes (magnified 200 times)

a. S. haematobium. S. mansoni. b. S. japonicum.

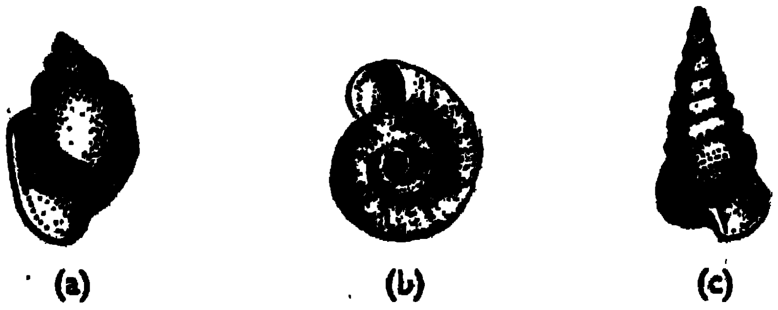


FIG. 77.—Snail hosts of schistosomes, slightly enlarged

a. Bulinus (S. haematobium). *b. Planorbis (S. mansoni).* *c. Oncomelania (S. japonicum).*

by (*a*) not walking or bathing in water containing snails (or which has contained snails during the last thirty-six hours), and (*b*) by not drinking unboiled water from natural sources.

The snails in which the flukes pass part of their life-cycle prefer slow-moving or still water, e.g. irrigation canals, ponds, and lakes, and the use of untreated water from such sources for bathing or drinking must be avoided.

SLEEPING SICKNESS—TRYPANOSOMIASIS

Sleeping sickness is an insect-borne disease occurring in tropical parts of Africa. It is caused by a one-celled animal (called a *trypanosome*—hence the scientific name for the disease[1]), living in the victim's blood-stream or lymph-vessels (see Fig. 78). These blood parasites live not only in Man but also in some domestic and wild animals, which thus provide a source of infection for Man. When a *tsetse fly* bites an infected person, it sucks up trypanosomes along with the blood, and after undergoing a series of changes in the insect's gut they make their way to its salivary glands, ready to be introduced into the next victim when the fly bites (see Fig. 79). Although tsetse flies feed mainly on other animals, they are always ready to bite human beings in daylight out-of-doors.

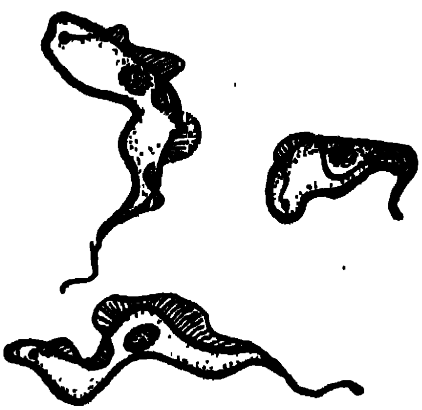


FIG. 78.—Trypanosomes in human blood (magnified 1,000 times)

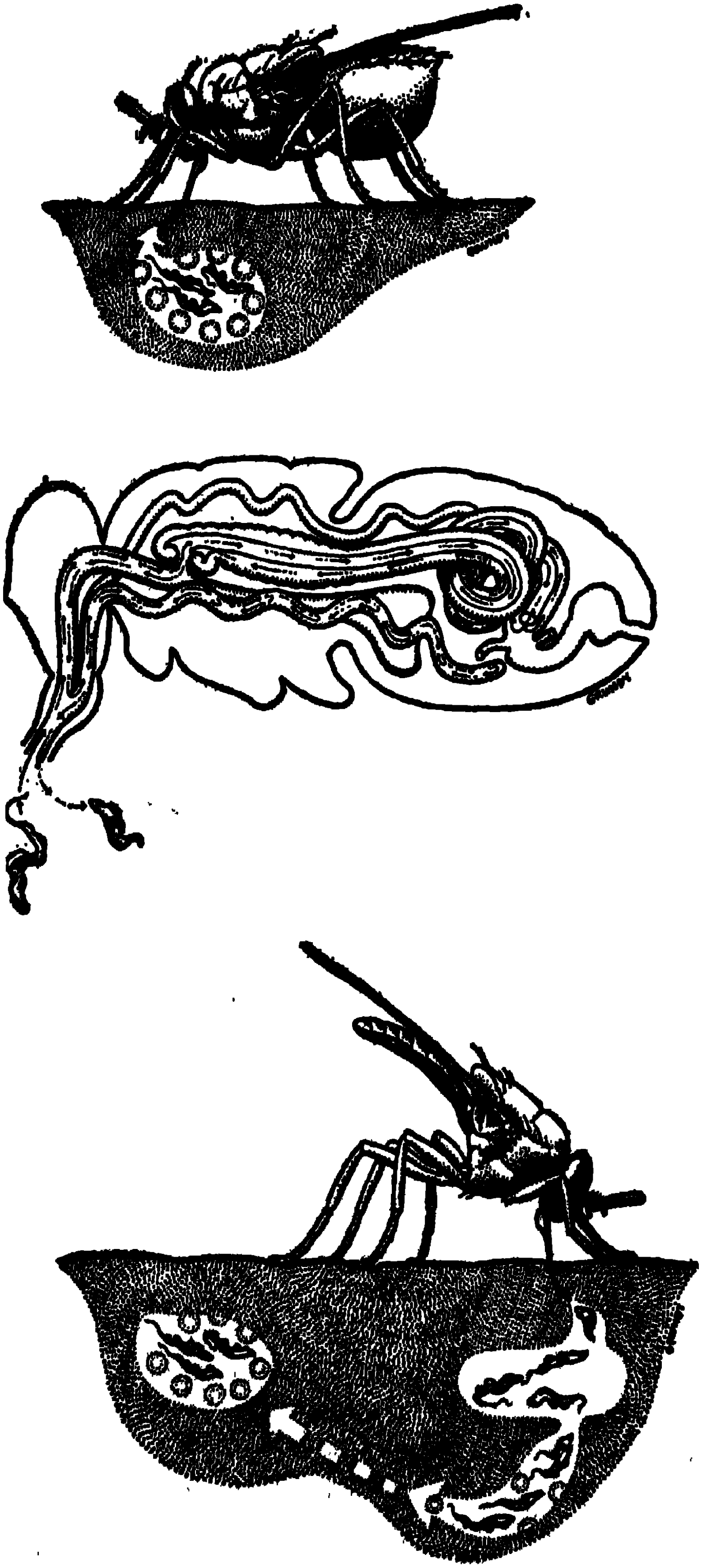
Sleeping sickness begins with fever resembling malaria and, if proper treatment is not given, the patient gets thinner and weaker until he dies of the disease. *Early* treatment with modern drugs, however, gives very successful results: another example of the importance of getting proper medical attention as soon as anyone is attacked by fever.

RELAPSING FEVERS

Relapsing fever is caused by the presence in the blood of tiny one-celled parasites called *spirochaetes* (from their spiral shape, see Fig. 80). These spirochaetes are carried either by lice or by soft ticks. About a week after

---

[1] *N.B.* Sleeping sickness (trypanosomiasis) must not be confused with 'sleepy sickness' (encephalitis), which is a virus disease whose transmission is not yet understood.



The tsetse fly (male or female) takes up the blood of the sick person, which contains trypanosomes

The trypanosomes enter the gut of the tsetse fly, and there they develop and increase in numbers by a process of division. The trypanosomes travel along the gut to the end of a lining membrane, and then they double back between it and the gut wall, passing into the proboscis and from there into the salivary glands

From the salivary glands the trypanosomes are injected into animals (or man) at subsequent feeds. The whole cycle in the tsetse fly occupies about 20 days

FIG. 79.—The trypanosomiasis cycle

Diagrammatic. The sizes of the parasites and tsetse flies are not in proportion to each other infection, the patient suddenly develops fever resembling malaria or sleeping sickness. Then, after a few days, his temperature goes down to normal and he thinks his illness is over until, a few days later, he has a *relapse* and the fever returns. Relapsing fever is a dangerous disease, hence it is important to have the blood examined under a microscope whenever anyone begins to get fever. Relapsing fever, in particular, must receive skilled medical treatment.

Tick-borne relapsing fever is carried by soft ticks that take in spirochaetes when they suck blood from an infected person. Then the spirochaetes multiply and make their way to the tick's salivary or other glands, so that when the infected tick next sucks blood, some spirochaetes enter the victim's body. In countries where tick-fever is common, it is important that the walls and floors of houses shall be free from cracks in which ticks may hide. Where such cracks occur, a suitable insecticide like BHC (benzene hexachloride) should be used to kill the ticks.

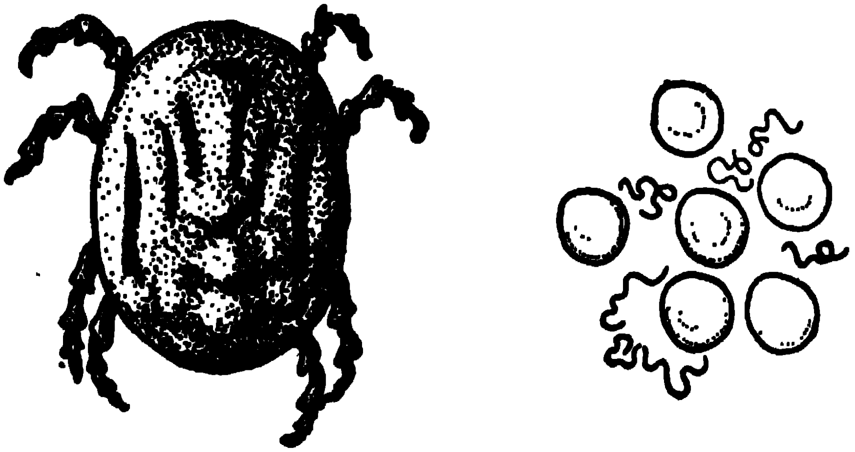

(a) (b)

FIG. 80

a. Soft tick (*Ornithodorus*) (magnified 4 times)

Carrier of one form of relapsing fever

b. Spirochaetes of relapsing fever in human blood, with red blood cells (magnified 1,000 times)

Louse-borne relapsing fever is transmitted by lice which have fed on infected blood. After multiplying inside the insect, the spirochaetes cannot escape unless the louse is crushed (e.g. by scratching). In this way the spirochaetes are set free on the victim's skin and may find their way into his blood. The prevention of louse-borne relapsing fever depends on the destruction of lice, and this has been discussed on p. 184 when dealing with louse-borne typhus.

CHAPTER 10

HYGIENE OF THE SKIN

In Chapter One we learnt that the skin protects the body from cold, wet, hurt, and invasion by bacteria. We have also seen that it plays an important part in regulating the body-temperature and that it plays a small part in getting rid of some waste products from the body. If the skin is to do this work properly, it must be kept *clean*. In hot countries, the skin gives off a lot of water, hence the sweat-pores must be kept clean. As the water in the sweat evaporates, a small quantity of solid matter is left behind. At the same time, the oil-glands in the skin give out an oily substance. Dead skin-cells and dust stick to this greasy layer of dried sweat, and if this dirty mixture is allowed to remain on the skin, it will become both unhealthy (since it harbours disease germs) and unpleasant (since it soon decomposes). The best way of cleansing the skin is with soap and water. Proper rubbing with soap is the only way to clean the skin thoroughly, merely standing beside a well or tap and throwing water over the body is not enough. A warm bath has the best cleansing effect, but tap-water in tropical countries is usually warm enough for the purpose. However, a warm bath (i.e. slightly below body-temperature) makes the sweat-glands in the skin more active, and the blood-vessels widen and thus increase the blood supply to the skin. If this is followed by a cold shower, the body gets a mild shock, the skin adjusts itself to the sudden change and the blood-vessels in the skin contract.

It is a good practice to give the skin a mild shock in this way, as it gets the skin into the habit of adjusting itself quickly to sudden changes of temperature. If the skin is then dried with plenty of hard rubbing (provided the skin is healthy and free from irritation, e.g. prickly heat), the skin muscles are exercised, the circulation again becomes active, and the whole body feels refreshed and full of vigour. Particular care should be taken, however, that the skin is dried thoroughly where two skin-surfaces are in close contact, e.g. between the toes, otherwise germs of skin diseases may attack these parts. It is a good plan after bathing to remove most of the water from the skin with a small towel (about one foot square), then dry the skin thoroughly with a larger dry towel. The small towel should then be well washed and hung up to dry ready for the next bath. Besides bathing the whole body at least once a day, we should wash the hands frequently, especially before meals, to avoid infecting the food. Dirty fingernails, too, often carry infection. They should be cut short and kept clean by scrubbing with a small brush.

Under hot and humid conditions, when sweat is produced more rapidly than it can evaporate, the skin may remain wet beneath the clothing, particularly around the waist and under the arm-pits. This sometimes causes *prickly heat* through irritation and inflammation of the skin. To prevent prickly heat the clothes should allow free ventilation. Shorts and a loose-fitting, short-sleeved, open-necked, coat-style shirt (worn outside the shorts—which should not be too tight round the waist) keep the skin well ventilated. In hot countries it is advisable to wear as few clothes as possible and to change them frequently, washing the clothes thoroughly with soap and then rinsing them in several changes of clean water until every trace of soap and dirt is removed. This final rinsing is very important because skin irritation may be caused by traces of soap or soda left in garments which come in contact with the skin. Ironing the clothes with a hot iron kills some organisms that cause skin troubles.

It is very important to keep the hair clean. It should be brushed and combed (using one's own personal brush and comb) every day to remove dirt and to increase the circulation of blood through the skin. Brushing also spreads the oil from the hair-glands along the hairs. The brush and comb should be washed every few weeks in cold water containing a little washing soda or ammonia, and then dried in the sun. A hair-brush should have stiff bristles, set wide apart. When necessary, hair-brushes can be sterilized by soaking in a weak solution of formaldehyde (e.g. one teaspoonful of 40 per cent. formalin in a pint of water). The hair should be thoroughly washed at frequent intervals with soap and warm water. If the hair is kept cut short, it is much easier to keep clean.

SKIN DISEASES

A number of skin diseases are caused by the invasion of the skin by *fungi*. Such diseases are particularly common in the tropics, where the high air temperature is very favourable to their existence. *Ringworm* is a skin disease of this type, caused not by a worm but by the growth of a fungus between the inner and outer skin. The outer skin falls off in small scales, exposing lighter-coloured, scaly parts beneath. Another type of ringworm attacks the skin of the head, growing among the hair. Ringworm is very infectious and can be spread by direct contact or by the use of an infected person's hair-brush, hat, clothing, or towel.

Dhobie itch is a similar disease caused by the growth of a fungus in the skin.

Another fungus of the ringworm type invades the skin between the toes, and the infection is spread wherever people walk bare-foot, e.g. around swimming-pools and in the changing-rooms of sports buildings (hence the common name 'athletes' foot' for this disease). This foot-itch can be very troublesome to cure, since the fungus may remain in the shoes, starting a new infection after the original foot-itch has been cured. The best protection is always to keep the feet clean and to dry them thoroughly after bathing, afterwards dusting with talcum powder. Loose-fitting shoes or open sandals (e.g. chaplis) help to keep the feet cool and dry.

All these fungus diseases are very difficult to cure once they have invaded the skin, since it is difficult to kill the fungus without also killing the surrounding skin, and they should be treated by a doctor as soon as possible.

Scabies

Scabies (or *the itch*) is a skin disease caused by a small animal—the *itch-mite*—about 0·3 mm. in length. The female itch-mite (see Fig. 81) bores under the outer skin, especially between the fingers, living in the skin and laying her eggs there. These hatch out in a few days and attack fresh areas of skin. Where the skin is thick, e.g. on the hands and feet, the track of the itch-mite can just be seen with the unaided eye as a fine raised line on the skin. Where the skin is thin, oval spots and watery blisters are formed. The skin itches so much that it is very difficult not to scratch. Scratching produces further trouble, since germs of other diseases may enter the skin, so that scabies is often the beginning of other skin diseases as well.

A person infected with scabies should go at once to a doctor, since very thorough treatment is necessary, and less than this is of no use. The patient's clothes, bedding, &c., must be disinfected by boiling or steaming. The itch-mite is usually transmitted from one person to another by direct personal contact, but it may also be picked up by handling infected clothing.

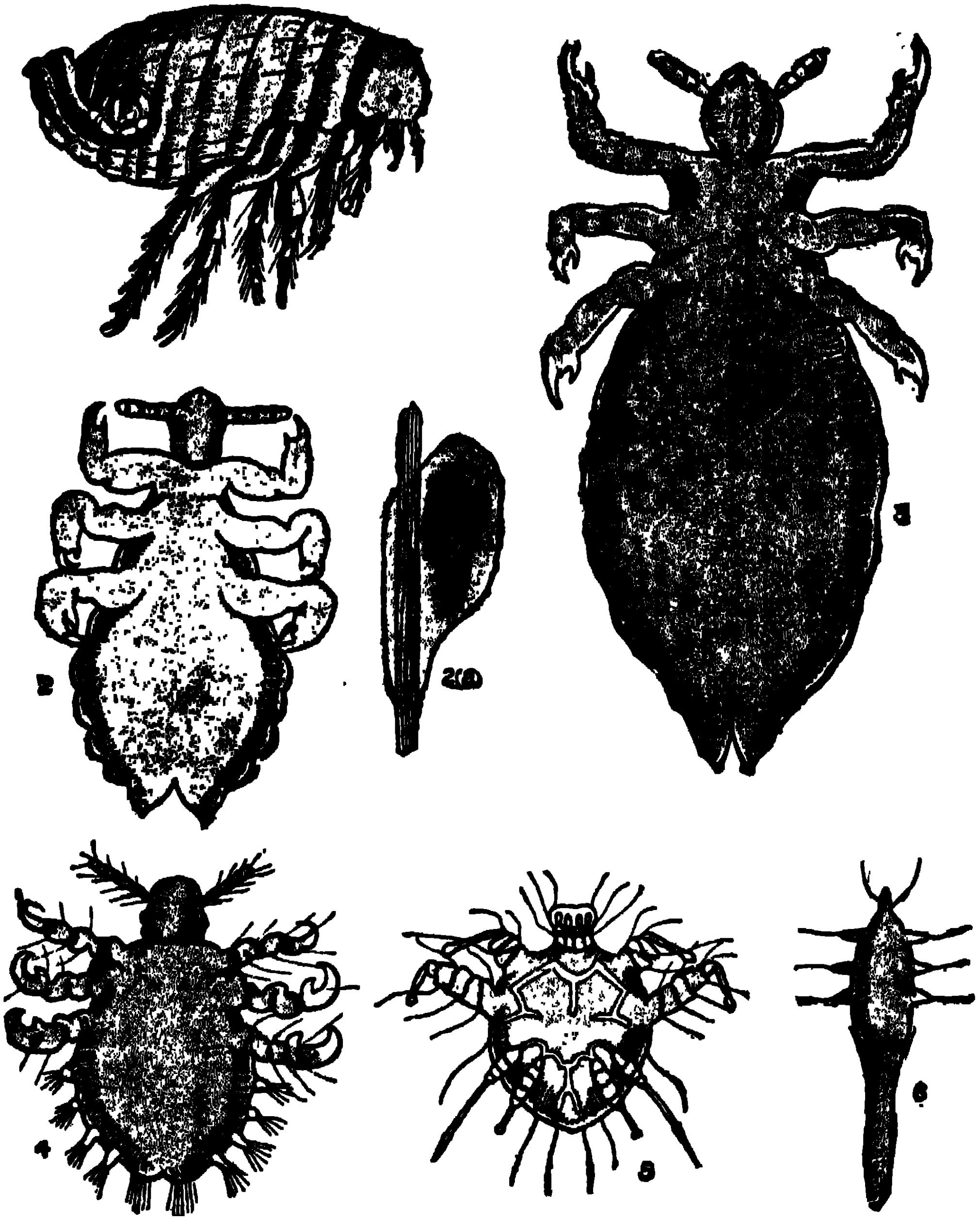


FIG. 81.—Some skin parasites of man

1—Flea (× 14). 2—Head Louse (× 10). 2a—Egg of Head-Louse (× 10) cemented to a hair. 3—Body Louse (× 14). 4—Crab-Louse (× 14). 5—Itch-Mite (× 50). 6—'Black-head' Mite (× 50)

Yaws

Yaws is a disease of the tropics, commonest in children, caused by the invasion of the body by a microscopic spirochaete. Although the disease shows itself on the skin, it may spread to the rest of the body, affecting the bones and sometimes even destroying the bones of the face. Fortunately, yaws can be cured quickly and completely if early treatment is given. Yaws spreads mainly by personal contact, but little children may become infected by sitting unclothed on infected earth floors. The disease first appears as a small swelling which becomes covered with a yellow crust. This first outward sign of yaws is called the 'primary yaw' or the 'mother yaw', and before it appears the patient will have suffered from headache, pains in the joints, and some fever. If no treatment is given, a large number of 'secondary yaws' appear six to twelve weeks later, accompanied again by fever, headache, and pains in the joints. This stage may last for months, and even for years.

The treatment of yaws is a matter for a doctor, and children suffering from yaws should be taken to a doctor at the first sign of the disease. With modern methods the disease can be completely cured.

It is very noticeable that the more highly civilized people in the tropics do not suffer from yaws, owing to greater bodily cleanliness, better housing, and an improved standard of living.

Leprosy

As one form of leprosy affects mainly the skin, the disease will be considered in this chapter. Leprosy is an infectious disease which is now most common in the warmer regions of the world. It is caused by invasion of the body by bacteria resembling those of tuberculosis, but the outward signs of the disease take a very long time to develop (from two to five years) and it is not quite certain how the germs enter the body. It seems that the germ enters through the skin of persons who are in close contact with leprosy patients for a long time, but the disease is by no means as infectious as tuberculosis. (For example, it is almost unknown for the staff of a leper-settlement to catch leprosy, and if the children of leprosy patients are removed from their parents at birth they do not develop the disease.) Leprosy bacteria live mainly in the body-tissues, but they are sometimes found in the blood and in nose-discharges, so that people living in close contact may breathe in infected droplets. Young children appear to catch the disease more readily than adults.

Although an advanced, incurable case of leprosy is easily recognized, the disease is extremely difficult to recognize in its early stages. Yet it is in these early stages that leprosy is curable. With modern treatment, also, although the more advanced cases cannot be cured, they can be stopped from discharging leprosy bacteria, so that they will no longer be sources of infection. When one considers that, for hundreds of years, leprosy was thought to be quite incurable, the advances made in recent years are remarkable.

In the most severe form of leprosy the bacteria are found chiefly in the skin, and this is the type of leprosy that spreads most readily. In its other form, the disease attacks the nerves, interfering with their working so that the affected areas become insensitive to pain, heat, and cold. The muscles also are affected and the arms and legs may lose much of their power of movement (i.e. they become *paralysed*).

The modern method of fighting leprosy is (i) to isolate the advanced cases in comfortable and attractive leper-settlements, where they can get the best treatment, and keep them there until they no longer discharge leprosy bacteria; (ii) to treat early cases before they begin to discharge germs of the disease and become infective (many of these early cases can be completely cured, thus the root of the leprosy problem is attacked); (iii) to keep a careful record of everyone who has been in close contact with each new case of leprosy as it is discovered, and to examine these contacts every six months for five years. In this way, any new cases of leprosy will be discovered in the very early stages, when the disease is curable.

If these three methods could be combined in any area where leprosy is common, the ancient problem of rooting out leprosy would be almost solved in another twenty years.

Lice

Although the existence of *lice* on the skin is not actually a disease, they cause great discomfort and may carry the germs of disease. There are three kinds of lice which live as parasites on Man: (i) *body-lice*, (ii) *head-lice*, and (iii) *crab-lice* (see Fig. 81). In hot countries, body-lice are found usually only on people who wear much clothing; they are seldom present on lightly-clad people. All three kinds of lice have hooked claws by means of which they cling tightly to hair and clothing. Body- and head-lice are very similar in size and appearance, and they vary in length from 1 to 4 mm. Crab-lice are much smaller, the body is squarer in shape and they remain still on one spot for a long time. Some of the mouth parts of a louse form a sucking-tube, while other mouth parts are used to pierce the skin.

After piercing the skin, the insect sucks blood. The bite of a louse causes itching, so that the victim scratches the skin, often producing sores which become infected with the germs of skin diseases. Besides this, lice may carry the germs of *louse-typhus* and one kind of *relapsing fever*.

Lice are spread by contact with lousy people, clothing, bedding, brushes,

&c., hence such contacts should be avoided. Personal cleanliness and frequent change of clothing also prevent lousiness, while if the hair of the head is kept short there is less risk of head-lice. Anyone with lice should have a hot bath and a complete change of clothing. If this is not possible, then DDT powder blown beneath the clothing will kill the lice (but not their eggs). The hair should be cut short and combed with a very fine comb which has been dipped in vinegar or soft soap to loosen the eggs. Since both lice and eggs are killed by moderate heat, infected clothing and bedding may be disinfected by baking at 70° C. for half an hour. Ironing with a hot iron is another simple way of killing lice in clothes. If typhus infection is suspected, then the lousy garments or bedding must be boiled or steamed to kill the rickettsiae that cause the disease.

Bed-bugs

The bed-bug is a small, flat, oval, and wingless insect of a reddish-brown colour and about 0·5 cm. in length (see Fig. 82). It gives off a characteristic, unpleasant smell (particularly when crushed) and lives in joints and cracks in furniture and buildings, coming out only at night in search of food (usually human blood). With some people bug-bites cause itching and inflammation, resulting in loss of sleep. The female bug lays a total of about 200 eggs, 20–50 at a time, usually in joints and cracks in wooden furniture, and these eggs hatch out in about ten days. The young ones begin to suck blood at once if they find a human being. The females begin to lay eggs at six or seven weeks old, and they live for many months. It is very difficult to rid a house of bed-bugs without skilled assistance from the health authorities, who use a gaseous disinfectant, e.g. formaldehyde. Cleanliness of the house and person is an important means of prevention. Sprays have little *direct* effect owing to the difficulty of

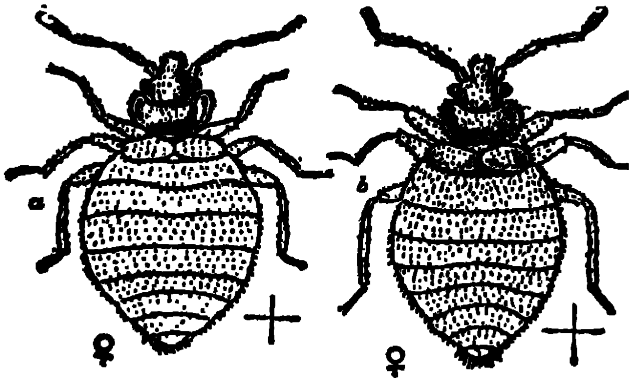


FIG. 82.—Female bed-bugs (× 5)

wetting the bug before it takes cover from the light, but if walls, beds, and other furniture are sprayed with DDT or BHC they can be kept free from bugs for several months.

Bed-bugs can live for many months without food and they can walk from one house to another. Hence one must be always on the look-out for their first appearance, ready to destroy them before they breed and multiply. The top corners of mosquito-nets should be examined every morning when the net is raised, for this is their favourite hiding-place in the daytime. If no bugs are found here, then one can be fairly certain that the whole room is free from bugs. Holes and cracks in woodwork should be filled with paint (or even soap), and brick and stone walls should be whitewashed to fill all holes that might be used by bugs for hiding and breeding.

Bed-bugs may cause ill-health, producing such irritation and misery that a sick person cannot get well and a healthy person may become sick. In some countries, if an old house becomes over-run with bed-bugs, it is deliberately set on fire and burnt, because there is no other way of dealing with bed-bugs once they are thoroughly established.

Sandfleas—Chiggers

The chigger (also known as the *chigoe* or 'jigger') is a kind of flea that lives in sand or soil (and often in the earth-floors of houses). The female insect, after fertilization, bores into the skin (usually under the feet) and lives there while her eggs develop, becoming several times her original size and producing a pea-like swelling under the skin. This causes an itching and burning pain so that it is difficult not to scratch. The chigger must be taken out whole so as not to infect the opening in the skin. This should be done very carefully with a clean needle (first sterilized by passing through a flame), and a mild antiseptic (e.g. iodine solution) should then be applied before the spot is covered with a clean dressing. People that do not wear shoes or sandals are obviously the most likely to get chiggers in their feet.

Ulcers

Among people living on a poor, badly-balanced diet, small skin injuries are usually slow to heal and often turn into painful *ulcers*. These *tropical ulcers*, which usually start near the ankle, soon spread over a large area of skin and may eat deeply into the flesh. Rest and proper medical treatment are necessary, together with an improved diet containing fresh fruit and vegetables, fresh milk, and vitamins A and D (e.g. in the form of red palm-oil, or fish-liver oil). To prevent the formation of tropical ulcers, even the smallest wounds on the feet and legs should receive prompt attention, being cleaned and treated with a mild antiseptic and then kept clean with a dressing held in position by sticking-plaster.

CHAPTER 11

REPRODUCTION

One of the characteristics which distinguishes living things from non-living matter is that *living things can reproduce themselves* while non-living things cannot. Except for some of the simplest one-celled organisms like Amoeba and the bacteria, all living things have a limited length of life and are finally overtaken by *death.* Many plants and animals meet their death 'by accident' before they grow old, e.g. they are often eaten by animals, they often die from lack of food, or they may be killed by parasites. But even those living things that escape 'death by accident' finally die 'of old age', e.g. the tissues 'wear out' or some essential part of the organism 'stops working'.

With the exception of the simplest, one-celled organisms, every *individual* living thing must die, but there is a continuous production of new individuals to replace the dead ones and thus maintain the *race.* These new individuals develop from small pieces of living matter which have separated from other individuals in the process of *reproduction.*

The simplest one-celled animals, like the one-celled plants, divide into two equal parts when they reach their full size, and each half develops as a new individual; but the higher animals, built up of many cells, all adapted for special functions, e.g. muscle-cells, nerve-cells, blood-cells, &c., have special *reproductive-cells—egg-cells* and *sperm-cells.* The egg-cells are produced in the female reproductive organs (the *ovaries*) while the sperm-cells are found in the male reproductive organs (the *testes*).

In the male mammal, the testes begin their development in the body-cavity, close to the kidneys, but before birth they pass hindwards into two sacs projecting from the posterior end of the body-cavity on the ventral side (the testis-sacs). Each testis is an oval body consisting of a large number of very fine tubes from the walls of which the sperms are formed. These sperm-producing tubes lead to a long, much coiled duct in which sperms are stored until required, when they pass along a sperm-duct leading from each testis. These two sperm-ducts join together and then open into the duct leading from the bladder to the exterior through the *penis,* or coupling organ, by means of which sperms are transferred from the body of the male to that of the female mammal. This common excretory and reproductive duct is therefore a passage for both urine and sperms. (In Man and some other mammals, e.g. the guinea-pig, there is also a pair of sperm-sacs, branching off from the sperm-ducts, in which the sperms are stored.)

In female mammals there are two ovaries on the dorsal wall of the body-cavity. These ovaries are very small white, oval bodies, and they produce egg-cells which are only about 0·01 inch in diameter. Ripe egg-cells are set free at intervals, and each egg-cell finds its way into the anterior end of the oviduct, where fertilization may take place if one of the sperms received from the male swims up the oviduct and fuses with the egg-cell. The fertilized egg-cell passes down an oviduct until it reaches a wider part of the duct (the *uterus*, or *womb*), when it attaches itself to the wall of this cavity and begins to develop. (In the guinea-pig and the rabbit, there are two such cavities, and several fertilized eggs may develop at the same time.)

The period of development inside the female parent's body varies in different mammals, e.g. it is about 3 weeks in rats, 9 months in Man, and 13–20 months in elephants. The developing embryo receives food and oxygen from the mother's blood-stream, and gets rid of waste material in the same way, the capillary blood-vessels of mother and embryo being in close contact (although not actually continuous—the embryo having its own independent blood circulation). When the young mammal is fully developed the muscular walls of the womb contract, forcing out the young one to begin its separate existence at *birth*.

Although a newly-born mammal can get its own supply of oxygen through its lungs, digest its own food and get rid of its own waste products, most newly-born mammals are very helpless and need a great deal of parental care. They are fed on milk, produced by special milk-glands of the female parent, and this milk supplies a complete diet which requires very little digestion to prepare it for absorption and assimilation. In the highest mammal—Man—there is a long period of comparative rest, during childhood, when parental care and protection reach their highest pitch and when the young one is trained and educated before being left to look after itself. The human body is not fully developed until about the age of twenty years, and under civilized conditions, the age at which human beings begin to 'earn their own living' tends to become later and later owing to the length of time required for training and education for skilled and specialized occupations. Under such conditions, the *family* becomes a very important unit of society.

CHAPTER 12

THE CONQUEST OF DISEASE

We have seen that many diseases are 'catching', i.e. they spread from man to man or from animals to men. Examples of such *infectious* or *communicable diseases* are the common cold, influenza, tuberculosis, typhoid fever, dysentery, ringworm, malaria, yellow fever, plague, the typhus fevers, tetanus, rabies, yaws, leprosy, and sleeping sickness. It is now known that all these diseases are caused by tiny living organisms of different kinds, and for convenience we often use one name for all such organisms and call them *germs*. But it is only during the last two or three hundred years that these microscopic germs have been recognized as causes of disease. Before that time, the *cause* of infectious disease was a complete mystery.

The first light was thrown on the problem about 300 years ago, when there was much argument about how living things arise. It was, of course, quite clear that the larger animals are the offspring of their parents and that the larger plants arise from seeds. But no one knew the life-history of the smallest living things. Some people said that these very small living creatures arose from non-living matter, while others argued that *life can only come from life,* i.e. living creatures must be the offspring of previous living creatures of the same kind. This kind of *argument* had gone on for centuries, but it was not until about 300 years ago that any *scientific test,* or *experiment,* was carried out, and an Italian named *Redi* first showed that the maggots which appear on decaying meat *did not come from the meat* (as most people then believed) but had hatched out of eggs laid on the meat by flies. He showed that if fresh meat is protected from flies no maggots ever appear, no matter how long the meat is left. But this type of experiment could be used only for living things that are big enough to be *seen* and it was not until the *microscope* was invented that still smaller living things (*micro-organisms*) could be seen.

About 250 years ago, *van Leeuwenhoek,* a Dutch scientist, discovered with the aid of the newly-invented microscope the existence of microscopic animals and plants, much too small to be seen by the unaided eye. About eighty years later, *Spallanzani,* an Italian scientist, actually saw one of these tiny one-celled micro-organisms divide into two. Then he saw these two divide into four, and so on, thus discovering that these tiny living things *reproduce themselves* and multiply like the larger plants and animals.

But it was nearly 100 years later (and less than 100 years ago) that *Pasteur*, a French chemist and one of the greatest scientists of all time, showed that even smaller living organisms, the *bacteria*, always arise from ancestors of the same kind, and he went on to prove experimentally that some diseases are caused by certain kinds of bacteria. Pasteur isolated the bacteria causing cholera in chickens and kept these bacteria alive and reproducing, *in culture*, in glass vessels in his laboratory. When he fed this cholera culture to healthy chickens, they very quickly developed cholera and died. Pasteur's great discoveries led to *the bacterial theory of infection* and this laid the foundation for the great advances of modern medical science.

Pasteur made a further great discovery when he fed some old and weakened cholera culture to healthy chickens, which, although they became sick, *did not die*. When they had recovered, he gave them some fresh, active, cholera culture, but the chickens were unharmed. Pasteur had made them *immune to chicken cholera*.

Pasteur did similar experiments on *anthrax* (a common disease among sheep) and on *rabies* (see also p. 164). In both cases he prepared a *vaccine* which would give healthy animals immunity from the disease.[1]

In Germany, *Koch* was following up and improving on Pasteur's experiments by isolating, culturing, and *identifying* the bacteria which cause anthrax, tuberculosis, and human cholera, and it was Koch who finally proved that many infectious diseases are caused by micro-organisms. The work of Pasteur and Koch was soon taken up and extended in laboratories in other parts of the world, and the bacteria causing typhoid fever, dysentery, diphtheria, and pneumonia were soon discovered.

As the result of these great discoveries, medical scientists were able, at last, to plan their attack on infectious diseases. They now knew that they were faced with three main problems: (1) *How to stop these germs from entering the body of a healthy person;* (2) *how to kill the germs in a sick person's body without harming the patient;* (3) *how to help the human body to kill disease germs for itself*. You should now be able to think of examples of all three methods for fighting infectious diseases.

---

[1] *N.B.* Although *Jenner* had discovered a method of *vaccination* against *smallpox* in 1798—long before Pasteur's time—neither he nor anyone else understood *why* it worked until Pasteur's work had led to the germ theory of infectious disease.

Infectious diseases, therefore, are caused by living germs that invade the body and multiply in it, feeding on it and living as *parasites* in the body-tissues. In most cases, it is the poisonous waste products (*toxins*) formed by such parasites that cause the ill-effects associated with each particular disease. In other cases the living parasites upset the structure and working of the body.

In the early days of the bacterial theory of infection it was thought that every infectious disease was caused by bacteria. But after their early successes with the diseases already mentioned, the bacteriologists were unable to isolate and identify the germs causing influenza, smallpox, yellow fever, measles, and rabies. They failed to find these germs simply because they were still smaller than bacteria, so that they escaped through the fine porcelain filters that stopped all bacteria. A *filter-passing germ* of this kind, too small to be seen under the most powerful ordinary microscope, is called a *virus*.[1] Unlike the disease-causing bacteria, the viruses will not grow and multiply outside the cells of their hosts, but they can be passed on from the sick to the healthy by the same means as bacteria. The name '*germ*', therefore, is applied to other disease-causing organisms besides bacteria, so when it was found that bacteria were not the only parasites causing infectious diseases, the bacterial theory of infection was widened into *the germ theory of infectious diseases.*

BACTERIA

Bacteria are the smallest known living things with a cellular structure. These colourless, one-celled micro-organisms (or *microbes*) exist wherever organic matter is found: in soil, in water, and in the air. Since most of them have no leaf-green (chlorophyll) they cannot use light energy in synthesizing their food, as do green plants, but they must get their food in other ways. In this, bacteria resemble animals, but since they are enclosed in a cell-wall they can only absorb dissolved food, thus resembling plants. But their cell-wall is not composed of cellulose, like plant cell-walls, and the modern view is that bacteria are neither plants nor animals, but form a separate class of living things.

Single bacteria measure from 0·0001 in. to 0·00001 in. and can only be seen under very powerful microscopes. Different kinds of bacteria have different shapes, being either spherical, rod-shaped, or spiral, and they often group themselves together in masses or in straight chains (see Fig. 83). Many bacteria can swim in water. In all of them the cell is bounded by a membrane (but not made of cellulose) and the organism cannot take in solid food. Bacteria are found everywhere—in the air, on dust particles, in water, in the soil. Although most of them do not contain chlorophyll, some can make their own organic food from simple inorganic materials: they do not, however, use light energy for this purpose. Others get ready-made food from dead plants and animals. Still others are *parasites*; they are able to enter other living organisms and take food from them. In doing so they cause disease in, or the death of, their hosts.

---

[1] Although viruses cannot be *seen*, they have recently been *photographed* by means of the new *electron-microscope.*

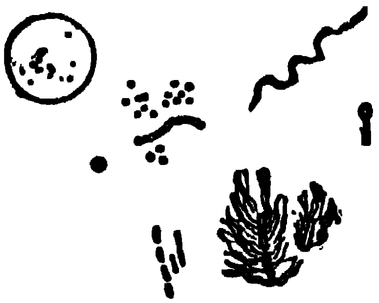


FIG. 83.—Types of bacteria (with a red blood-cell A to show relative size) (magnified about 1,000 times)

Bacteria reproduce themselves by splitting into two, and the two new bacteria grow so quickly that they are ready to divide again in about thirty minutes. Hence, in ten hours, a single bacterium can produce over a million bacteria. When conditions are unfavourable, e.g. when the liquid in which they are living dries up, some bacteria produce *spores*, and in this form they may be scattered in all directions, floating in the air, ready to germinate when they reach a suitable situation. These tough-walled spores are the most resistant form of living matter. Some bacterial spores have been known to germinate even after being kept in liquid air (at − 190° C.) for six months, but practically all spores are killed by boiling for twenty minutes.

Everyday importance of bacteria

Bacteria have a very important influence indeed on other organisms. Soil bacteria are partly responsible for the nitrogen and carbon cycles; in particular the nitrogen-fixing bacteria of the legume root-nodules improve soil fertility. The breakdown of organic materials in soil largely benefits the higher plants and animals. The bacteria which live in the intestines of grazing animals digest the cellulose in their food and in this way provide the animals (and themselves) with sugar.

Man has even learned to use some bacteria almost as 'domestic plants'. Thus the 'curing' of tobacco, the ripening of cheese, and the making of vinegar are all reactions carried out by bacteria. To Man, however, the bacteria are not an unmixed blessing. With the moulds and other fungi they are largely responsible for spoiling foods like milk, butter, eggs, and meat. Moreover, many of the important diseases of Man (e.g. tuberculosis, typhoid fever) have now been shown to be due to the activities of parasitic bacteria.

FOOD PRESERVATION

When we handle food in large quantities we must use methods which reduce the chances of its being spoiled by bacteria. In this way much waste can be avoided and, what is more important, the production of poisonous substances (toxins) in the infected food can be prevented. The most useful methods are:

(1) *Sterilization* of the food and its container by *heat*. Thus we heat fruit and vegetables just before bottling or canning them; we 'pasteurize' milk by heating it to not less than 142° F. for thirty minutes,[1] thus destroying most of the harmful bacteria. Canning and bottling have the additional advantage of excluding air from the vessels. Few bacteria and no moulds can grow in the absence of oxygen.

(2) *Cold storage*, which slows down the growth of all bacteria. Refrigerators are becoming more common each year in homes and food shops, and meat and other foods are transported round the world in refrigerated ships.

(3) The use of *fly-proof safes* and kitchens. Flies carry bacteria from place to place on their bodies; because they feed on refuse, they are dangerous carriers of disease germs.

(4) *Desiccation*. Food to be used by people living at a distance from farms (e.g. by soldiers on service) is now often dried. This has two advantages—it reduces the weight of the food, while the lack of moisture prevents bacterial growth. If the drying is carried out properly, most foods retain some at least of their valuable vitamins.

PREVENTION OF BACTERIAL DISEASE

It is not easy to prevent the entry of bacteria into the human body, where they may cause disease. In all modern civilized States the Health Departments do their best to reduce the chances of bacterial infection by:

(*a*) Ensuring a water supply free from dangerous bacteria; usually it is filtered or sterilized with chlorine.

---

[1] Or to 162° F. for 15 seconds.

(*b*) Ensuring a 'safe' milk supply; e.g. the milk is often 'pasteurized' to kill the bacterium causing tuberculosis.

(*c*) Safe disposal of sewage; e.g. the faeces of infected persons contain the bacteria causing *typhoid* and *dysentery*.

In hospitals today great precautions are always taken against bacteria, e.g. instruments and dressings are sterilized by heat just before use. If these methods fail, many of the recently discovered chemical substances like the '*sulpha*'-*drugs* and *penicillin* can be used to stop the growth of some kinds of bacteria without harming the patient. Some bacteria cause disease largely because they produce *toxins* in the blood; sometimes the body cures itself by producing an *anti-toxin*. The careful study of these and of the means of producing them gives the doctor yet another weapon in his fight against bacterial disease.

Disinfection

As so many diseases can only develop as the result of *infection* by disease-germs, it is clearly important to find ways of killing such disease-germs. *Disinfection* means the destruction of disease-germs, usually while they are outside the body, and a *disinfectant*, or disinfecting-agent, is something that actually kills germs. An *antiseptic*, however, only stops the growth and multiplication of germs and does not necessarily kill them. But this is very useful when we want to check the spread of infection from a wound to the rest of the body. In such cases, a strong disinfectant would kill the healthy cells as well as the harmful germs. A suitably mild antiseptic checks the growth of germs without damaging the surrounding tissues.

The first proper use of antiseptics was made by *Lister*, a British surgeon, who, hearing of the discoveries made by Pasteur and Koch, realized that these had important applications to surgery. At that time, surgical operations were highly dangerous because most of the patients died—not during the actual operation but through 'blood-poisoning' which set in afterwards. Lister, suspecting that the pus produced in such cases was the result of bacterial infection, tried experiments in which everything used in his operations was soaked in a solution of carbolic acid (or phenol) which kills bacteria. No pus was formed after his operations and the death-rate among surgical cases was remarkably reduced. Carbolic acid, however, although it *kills* germs also damages healthy tissues (it is a disinfectant rather than an antiseptic), so Lister tried milder chemicals strong enough to check the growth of bacteria without damaging the patient's tissues. This was Lister's *antiseptic* method, which completely revolutionized surgery and the treatment of wounds by preventing *sepsis* (infection of tissues with pus-forming bacteria). A still later advance was the *aseptic* method, designed to *exclude* germs completely from the exposed tissues. This is the method used in modern hospitals where the air, walls, and fittings of the operating theatre are kept free from dust and germs and where the outer clothing of the surgeon and his assistants is made *sterile* (or free from germs). Everything used in the operation, e.g. scissors, forceps, dressings, &c., is *sterilized* by steam before being used and is handled only by people wearing sterile rubber gloves. The *aseptic* method is the ideal way to treat wounds, since it is obviously better to exclude germs rather than try to destroy them after they have invaded the tissues.

Disinfecting-agents

It is convenient to classify disinfecting-agents as (i) *natural disinfecting-agents,* (ii) *physical disinfecting-agents,* and (iii) *chemical disinfectants.*

Natural disinfecting-agents

The natural disinfecting-agents are *fresh air* and *sunlight,* and we have learnt that most disease-producing micro-organisms soon die if they are exposed to air and sunlight. Out-of-doors, in fresh, moving air, it is almost impossible to 'catch' an infectious disease. Houses, therefore, should be well lighted and well ventilated. It is also a good practice to leave bedding and clothing exposed to bright sunlight for several hours each week. For example, typhoid bacteria are killed by exposure to strong sunlight for an hour or two.

Physical disinfecting-agents

Heat is one of the best disinfecting-agents, since most harmful bacteria are killed at 100° C. (the temperature at which water boils in an open vessel). Small articles that have been used by a sick person can be disinfected in the home by boiling in water for at least twenty minutes. The cheapest and most efficient way of applying heat to larger articles of clothing and bedding is by using *steam,* because steam at 100° C. contains more heat energy than does boiling water at the same temperature, e.g. when 1 g. of steam at 100° C. comes into contact with any material whose temperature is below 100° C. it sets free 536 gram-calories of heat energy in condensing to water at 100° C. (see p. 276). This principle is applied in *steam-disinfectors,* which are of two main types: (*a*) *high-pressure disinfectors* using steam at a pressure of about 20 lb. per sq. in., and (*b*) *low-pressure* *disinfectors* using steam at about 5 lb. per sq. in. The high-pressure type is the more efficient (since it uses steam at a higher temperature), but it needs a skilled attendant to operate it safely, hence this type is used mainly in large hospitals and in the public health departments of large cities. The low-pressure type requires less expert supervision and the temperature it produces is not high enough to damage woollen articles.

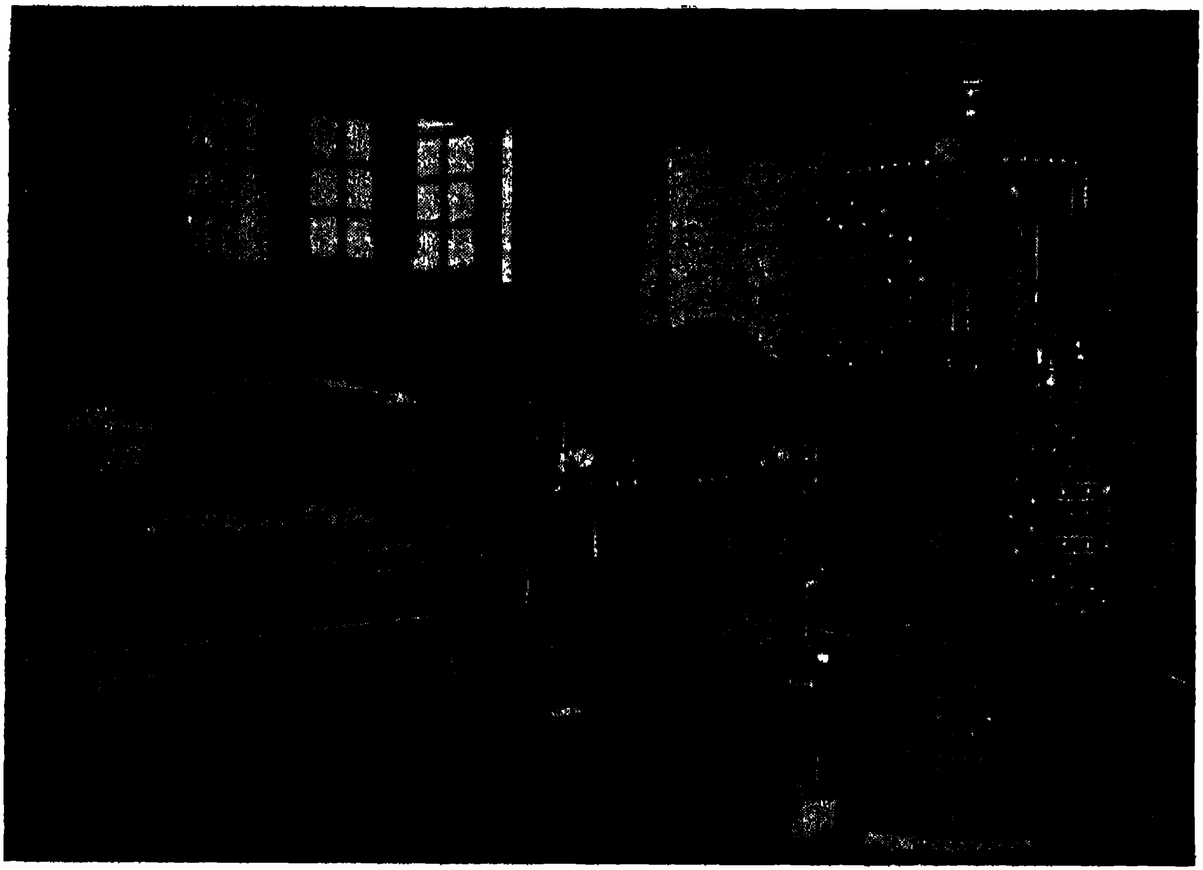


FIG. 84.—'Thresh' high-pressure steam-disinfector

The vertical boiler on the right supplies high-pressure steam to the horizontal disinfecting chamber on the left of the picture. The chamber is built into the wall separating two rooms. One room is used only for infected articles and the other room only for disinfected articles. Infected articles are put into one end of the apparatus and the disinfected articles are taken out of the other end, thus preventing re-infection.

In both types of steam-disinfector, infected articles are placed in an iron chamber (see Fig. 84) and the doors are tightly closed. Steam is then passed through the chamber under pressure.

In the high-pressure type, before steam is admitted air is removed from the chamber, thus producing a vacuum so that when steam is forced into the chamber at a high pressure it penetrates into all the spaces in woven materials formerly filled with air. After disinfection is complete, a vacuum is again produced in the chamber to remove as much moisture as possible from the disinfected articles. A current of hot air is then passed through the chamber to complete the drying process.

In the low-pressure type, a *current* of steam is passed through the chamber, driving out all the air, so that the steam penetrates right inside the porous clothing or bedding material. The steam is turned off after half an hour and hot air is then passed through the chamber to displace the steam and to dry the disinfected materials. Fig. 85 shows a small 'home-made' steam-disinfector suitable for use in places out of reach of the larger and more elaborate disinfectors.

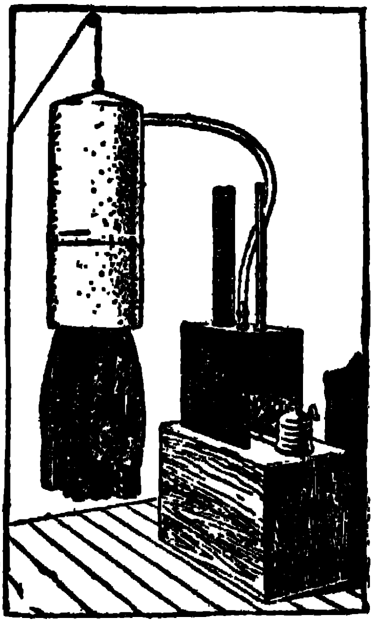


FIG. 85. — 'Sack' steam-disinfector

Showing boiler, oil-burner, and clothing ready to be drawn up into 'sack'.

Chemical disinfectants

Chemical disinfectants are used either as gases or in solution. The commonest chemical disinfectants are (i) 'coal-tar' disinfectants, (ii) formaldehyde, and (iii) either quicklime or slaked lime.

(i) *'Coal-tar' disinfectants:* These are substances such as Cresol (1 per cent. solution), 'Lysol' (1 per cent.), and carbolic acid or phenol (5 per cent.). Infected articles can often be disinfected by soaking them in solutions of the above strengths.

(ii) *Formaldehyde:* Formaldehyde is a very powerful and very useful chemical disinfectant. It is a gas, but it is usually kept dissolved in water. 'Formalin' is a 40 per cent. solution of formaldehyde in water. A 10 per cent. solution of formalin is a very useful general disinfectant. It can be used for disinfecting urine, faeces, and sputum; it does not damage cotton, wool, or silk clothing, and it has no bleaching action. In fact, formaldehyde can be used to disinfect almost anything except leather (which it hardens).

Formaldehyde can also be used as a spray. It is much easier to disinfect a room by spraying the floor, ceiling, walls, and furniture with a 2 per cent. solution of formaldehyde than by using a gaseous disinfectant like sulphur dioxide. This spray method is particularly useful in tropical countries, where it is often so difficult to make a room air-tight before disinfection.

(iii) *Lime:* Both quicklime and slaked lime are cheap and efficient disinfectants, hence the value of whitewashed walls and ceilings. Whitewash is made by mixing one part of freshly slaked lime with about four parts of water.

For ordinary, everyday purposes, 2 per cent. formaldehyde is used for spraying, 1 per cent. Cresol (or 'Lysol') for washing infected clothes and bedding and for adding to lime-wash when whitewashing walls and ceilings.

In general, no disinfecting-agent can do its work unless it comes *into contact* with the micro-organisms which cause disease, and if these are protected by dirt much disinfectant is wasted. *Disinfectants can never serve instead of cleanliness. Remember that sunlight, fresh air, soap and water, and scrubbing are the oldest, best, and cheapest disinfecting-agents.* Disinfectants should not be used to hide bad smells, they must be applied directly to the bacteria which are producing the smell. Most stinks are harmless in themselves; they merely indicate bacterial action somewhere in the neighbourhood.

Infected air should be removed by *ventilation*, since it is impossible to kill all the bacteria in air with disinfectants and still keep it fit for breathing.

In general, disinfectants are no substitute for cleanliness, for infection with the 'filth-diseases' arises mainly from *contact* with dirty hands and dirty drinking-cups and eating-vessels. The first essential is to attend to the people carrying the germs.

CHAPTER 13

PUBLIC HEALTH SERVICES

'Public health is the science and art of preventing disease and improving health through organized communal effort.'

Under primitive conditions, each separate family or group of families has to look after its health and sanitation without outside help. Under modern civilized conditions, with many people living close together in towns and villages, although each person can do much to keep his own body in good working order, there are many health measures which are beyond the control of individuals. For example, it is of little use for one household to try to keep its compound free from rats, flies, and mosquitoes if the neighbouring compounds are breeding-grounds for them. Also, in towns and villages, a person seldom knows the original source of all his food and how it has been prepared or handled before it reaches the market or shop. It is better (and cheaper) for the Public Health Service to look after all those matters which prevent disease, and thus safeguard the health of the whole community.

In a modern civilized community, the public health service looks after the following: (i) *water supply*, (ii) *refuse disposal*, (iii) *purity of food supplies*, (iv) *control of housing conditions*, (v) *control of infectious diseases*, (vi) *registration of births and deaths*, (vii) *school medical inspection and child welfare*, and (viii) *health education* (in partnership with the schools).

WATER SUPPLY

A good supply of clean water for drinking, cooking, and washing is one of the first essentials for healthy living. There is seldom any difficulty about this in most large towns, where the water is purified and filtered before being supplied to houses. But in many country districts the water supply is not under proper control and may contain harmful impurities, e.g. parasites that cause disease. In some countries people use rain-water collected from their roofs and stored in tanks. This is not an ideal arrangement since birds (and sometimes rats) leave their droppings on roofs and in rain-water channels and thus contaminate the water. So this rain-water should always be boiled before drinking it.

In many country districts, where there is no piped supply of purified water, the domestic water supply is obtained from lakes, rivers, or smaller streams. Such water should always be regarded with suspicion since it has usually been exposed to contamination. It is always risky to drink from a stream, for it may have been contaminated higher up in its course. The *appearance* of water is no guide to its suitability for drinking. A sample of water may be clear and sparkling to look at, and free from unpleasant taste or smell, and yet contain disease-bacteria and the organic matter on which they feed.

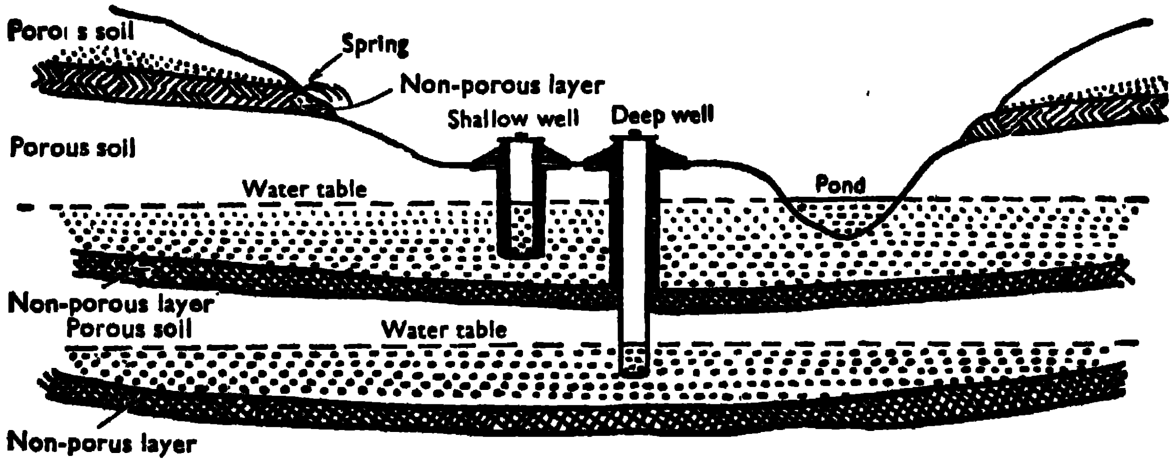


FIG. 86.—Water-bearing layers and wells

Water from *deep* springs and *deep* wells is usually free from suspended impurities (including bacteria) and safe to drink if the source is properly protected against contamination, e.g. there should be no latrine, cattle-shed, or manure heap within at least 100 ft. of the well. A spring should be built-in with bricks, stones, and cement (to exclude contaminated surface-water and dirt) and the water led away through a pipe into a covered tank from which water is taken by a pump (and *not* by dipping with a bucket) or from an outlet-pipe fitted with a tap. In this way, the water cannot become contaminated between leaving the spring and reaching the supply-point.

Shallow wells or *water-holes* are always dangerous since they collect mainly surface-water and sub-soil water which has not been thoroughly filtered by passing through a considerable depth of earth (see Fig. 86).

A *deep* well, however, is one where the water reaches the well *from below* and not by drainage from above (see Fig. 86), because there is a non-porous layer of rock or clay between the water-level and the surface. The well should have a water-tight lining, e.g. bricks set in cement, or ready-made concrete pipes of large diameter, extending down as far as the non-porous layer and projecting upwards two or three feet above ground level (see Fig. 87). The top of the well should have a close-fitting cover and there should be a circular outward-sloping well-head of concrete at least 12 ft. in diameter so that if water is spilled near the well it will flow away to the side and not drain down through the soil near the well (see Fig. 88).

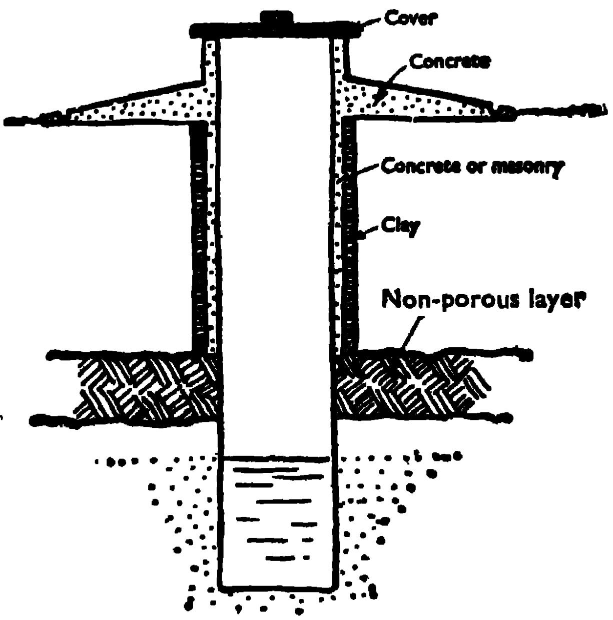


FIG. 87.—Deep well, simple type

The well passes through the first non-porous layer and the lining reaches that layer. The lining should be water-proof, to prevent entry of water from soil above the non-porous layer.

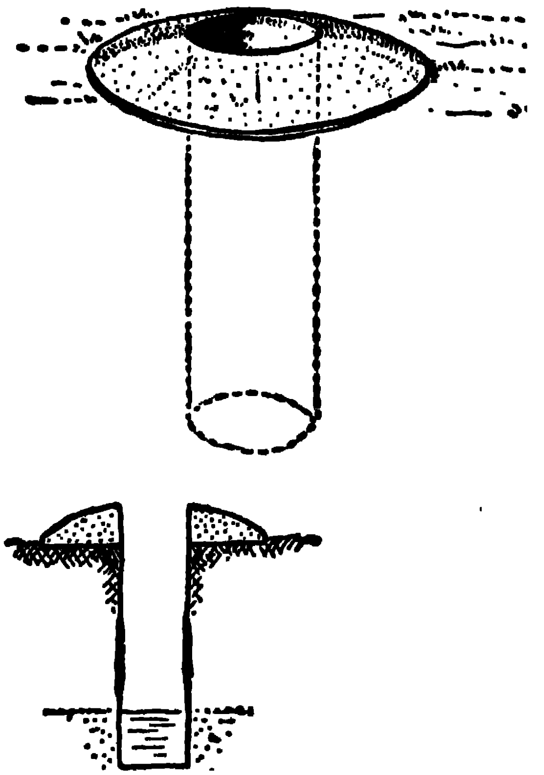


FIG. 88.—Well-head of concrete

Simple type to prevent drawn water from re-entering the well.

The best arrangement is shown in Fig. 89, where a pump is used to raise the water without removing the cover from the well. This is a much safer method than lowering buckets into the open well, for one can never be sure that the buckets are clean. Well-water used for drinking and cooking should be tested periodically by the local health department.

The easiest and best way to make a small quantity of water safe for drinking, tooth-cleaning, and dish-washing, is to boil it for at least ten minutes. The use of household filters is not so safe as boiling, since if the filter gets dirty it will serve as a breeding-ground for disease organisms and will then do more harm than good. Hence if there is the slightest suspicion that a water supply is not 'good water', the best thing is to boil every drop of water used for drinking, tooth-cleaning, and washing cooking-vessels.

The common Chinese custom of always drinking tea and never plain water has a sound hygienic basis, since it ensures that the water is always boiled before being used for drinking.

A properly protected deep spring or deep well can provide a safe water supply for a family or small community, but in larger communities, e.g. towns and large villages, it is preferable to have one big public supply rather than large numbers of small wells. This is done by collecting water from a natural source situated in a nearby uninhabited *catchment-area* (e.g. a forest-covered valley running up into the hills), treating the water to make it safe and then distributing it through underground pipes. The public health authorities undertake the responsibility for seeing that the public water supply is pure.

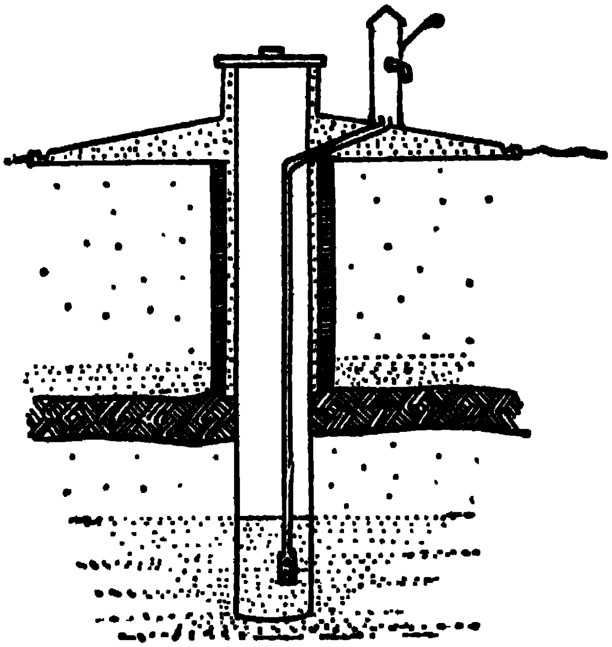


FIG. 89.—Deep well, with pump

Large-scale purification of water

There are usually three main processes used in treating town water supplies:

(i) *Settling (sedimentation).* The most dangerous impurities in water to be used for drinking and domestic purposes are *suspended* in the water

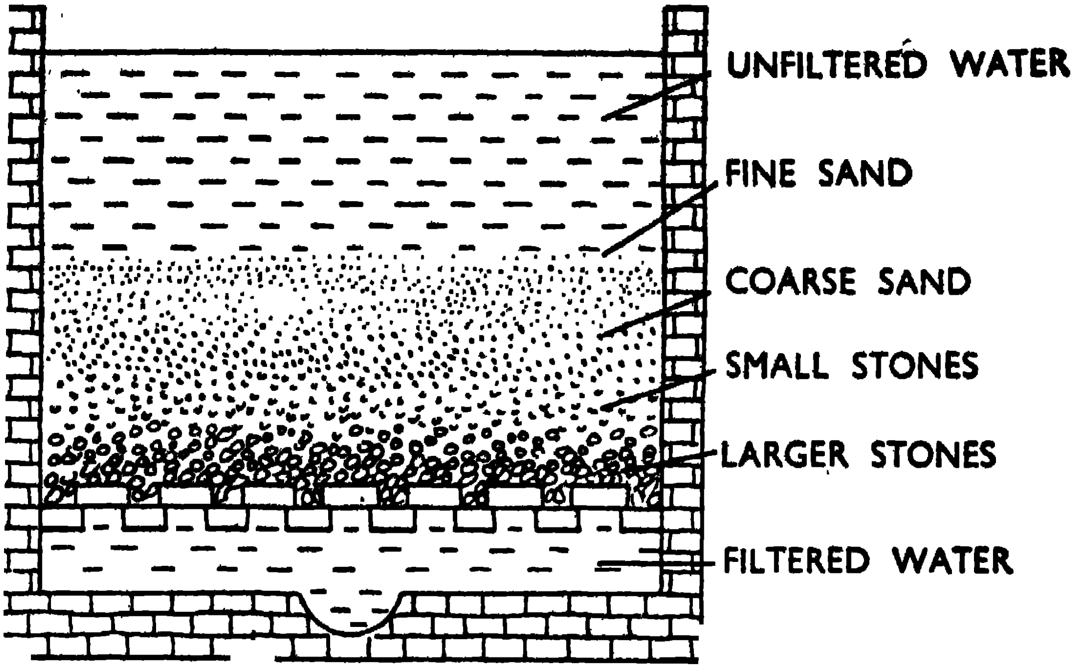


FIG. 90.—Sand-filter

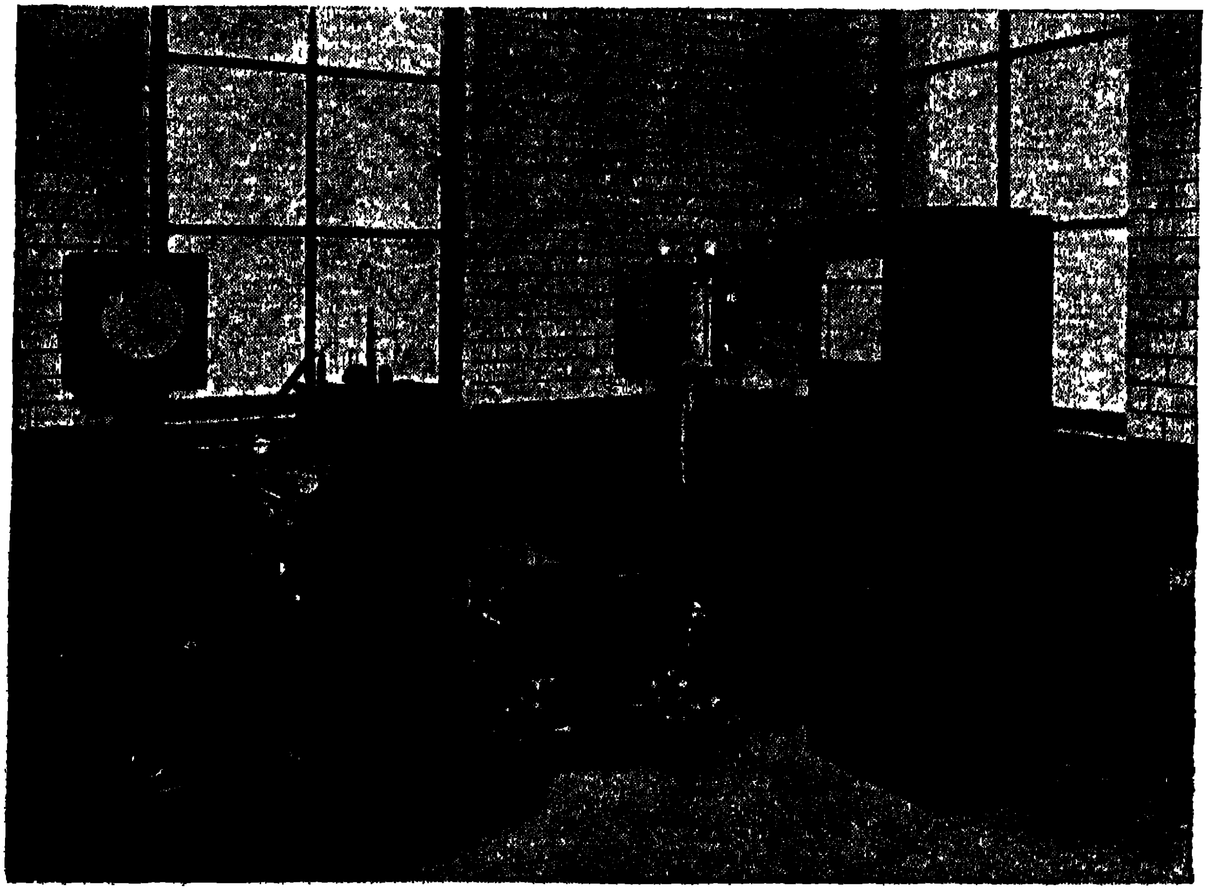


FIG. 91.—Chlorination plant at a city water-works

and NOT dissolved in it. The water is first collected in large open tanks or reservoirs and left to stand quietly for several days, at least, while the heavier particles, e.g. fine mud and decayed vegetable matter, sink to the bottom. Exposure to air and sunlight also kills many harmful bacteria. Chemicals (e.g. alum) are sometimes added to form a jelly-like *precipitate* which gradually settles to the bottom, carrying down other suspended matter with it.

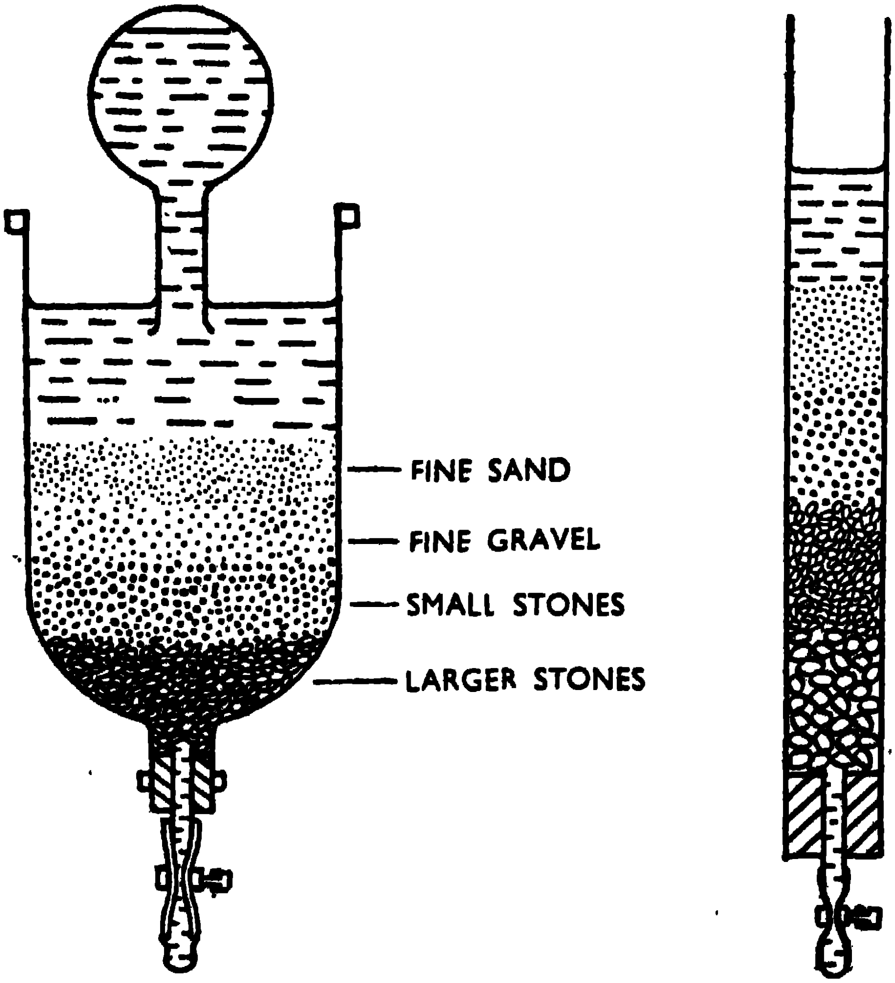


FIG. 92.—Model slow sand-filters

(ii) *Filtering*. After removing most of the suspended matter by sedimentation in the settling-tanks, the water is *filtered* through a bed of clean sand (see Fig. 90). This removes the smaller suspended particles (including bacteria) which did not fall to the bottom of the settling-tanks.

(iii) *Chlorinating*. To make quite sure that all bacteria are destroyed (in case any get through the sand-filters) the water is disinfected with *chlorine* (a poisonous greenish-yellow gas with a pungent smell), which kills bacteria (see Fig. 91). Only a small quantity of chlorine is needed:

about one part of chlorine to every million parts of water. This is too little to do any harm to people drinking the water.

Water which has been passed through a well-organized water-works before distribution through supply-pipes is safe for drinking and all domestic purposes. Such a supply, regularly tested for purity and freedom from bacteria, protects the community against water-borne diseases like cholera, typhoid, and dysentery.

Set up a model slow sand-filter as shown in Fig. 92, using either an inverted bell-jar (or a large bottle with its bottom cut off) or a wide glass tube. At the bottom put a layer (about 2 in. deep) of pebbles (about ½ in. diameter), then a 2-in. layer of smaller pebbles, then a 2-in. layer of fine gravel, then a 4-in. layer of fine sand. (A layer of coarsely crushed wood charcoal may be put below the sand to decolorize brown, peaty water.) The water should drip *very slowly* from the bottom of the filter, the flow being adjusted by means of a spring-clip and piece of rubber tubing, and the model will not work perfectly until the top of the 'filter-bed' has become covered with a slimy 'vital layer'. The model filter must not be allowed to dry out between experiments.

THE DISPOSAL OF WASTES

In his primitive state, when Man roamed about the open country, he left his wastes and excreta behind him and moved on elsewhere. But as Man began to accumulate property and build permanent houses and villages he had to face problems of sanitation and the disposal of wastes. In any settled family or community—village, town, or city—the most important health problem to be faced is the disposal of human faeces, because so many human disease germs are passed out with the faeces, and if these infected faeces are allowed to contaminate water or food, then the diseases are spread.

Disposal of human excreta

There are several methods for the safe disposal of human excreta (i.e. faeces and urine) suitable for use under various living conditions: *pit latrines*, *bore-hole latrines*, *bucket latrines*, *septic tanks*, and *sewerage systems*.

Pit latrines

The simplest and cheapest way to dispose of excreta from a single family is to use a hole or pit in the ground. A pit latrine is quite satisfactory in well-drained, porous earth if it is dug deep enough, i.e. not less than 6 ft. (and more than 10 ft. deep if this is possible without reaching the ground-water level) (see Fig. 93). If the ground-water level is only a few feet below the surface, then a large mound of tightly-packed earth should first be made, at least 6 ft. across and several feet high, and a pit then dug down through the centre of the mound to give the necessary depth. The pit should be covered with a *strong* wooden platform fitted with a latrine box-seat and lid or (better) a squatting-plate. Flies will not enter a deep, well-covered pit since they dislike darkness. A deep pit latrine dug in porous soil can be used by a family for several years, since it is self-cleansing owing to bacterial action which liquefies the faeces so that they gradually soak away into the surrounding earth. If the pit is too small for the number of users or if the soil is insufficiently porous it gradually fills up, and when about half-full it should be filled in with earth and a new pit dug some distance away. A pit latrine should be in a light wooden building with an overhanging roof so that rain-water cannot enter the pit but is thrown clear, to be carried away by a drain surrounding the latrine.

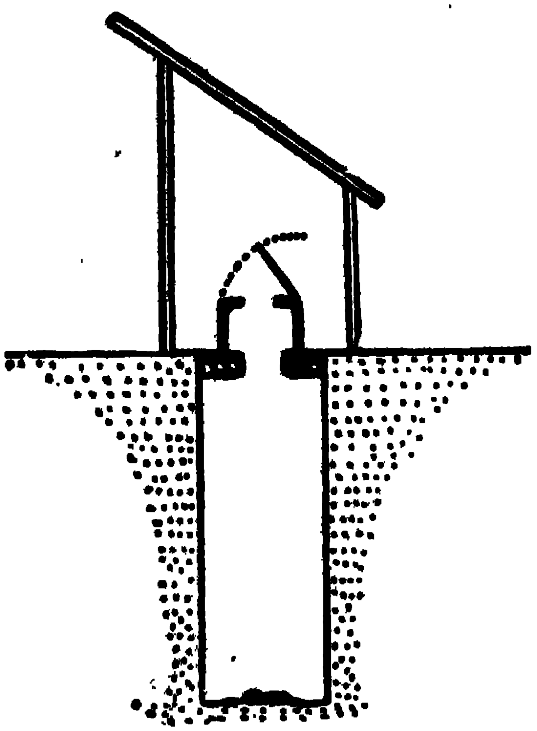


FIG. 93.—Pit latrine

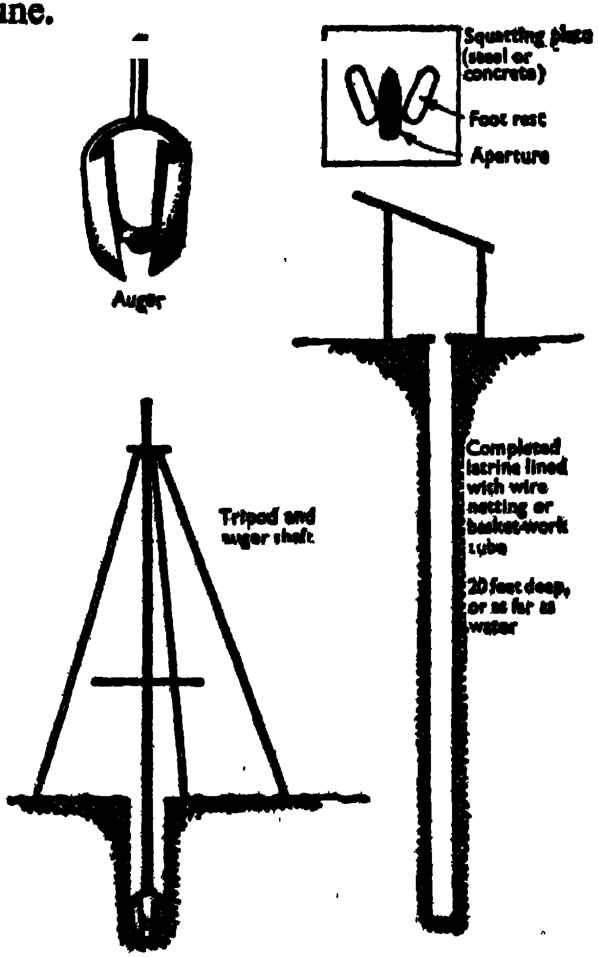

Auger
Squatting place (steel or concrete)
Foot rest
Aperture
Tripod and auger shaft
Completed latrine lined with wire netting or basket-work tube
20 feet deep, or as far as water

FIG. 94.—Bore-hole latrine

Bore-hole latrines

These are made with a special boring-tool (or *earth-auger*) which cuts a hole 16 in. in diameter to a depth of 20 ft. or more if the ground is not too rocky (see Fig. 94). In practice, boring is stopped when the ground-water level is reached. If the surrounding soil is soft and crumbly, the sides of the bore-hole can be prevented from falling in by a lining of basket-work or fine wire-netting, but when the surrounding soil is firm (e.g. laterite) it is only necessary to line the top of the bore-hole with galvanized iron to make cleaning easier. The top of the bore-hole should be closed with a concrete squatting-plate (with a lid), which provides the most natural position for the user and which is more easily kept clean than a box-seat (see Fig. 94). A deep bore-hole of this type makes a most efficient latrine for a single family if the soil is suitable, for the latrine is almost self-cleansing and can be used for a very long time. Most public health authorities have the necessary earth-auger for boring the hole, and a small boring-team of men can make a deep bore-hole latrine in a few hours. Under suitable conditions of soil and situation, this is the best family latrine for country districts.

It should be borne in mind, however, that no pit latrine or bore-hole latrine should be less than 100 ft. from a well or other source of drinking water. Farther away than this is even better. To find out whether such a latrine is contaminating a near-by well, a strongly-coloured dyestuff (e.g. fluorescein) is poured into the latrine and samples of water are then taken from the well at hourly intervals. If the well-water becomes coloured then the latrine is contaminating the well, and a new latrine must be dug farther away or at a lower level. Kerosene (paraffin) is sometimes poured into the latrine instead of dyestuffs, and the taste and smell of the well-water shows whether the latrine is contaminating the drinking-water.

Bucket latrines

Pit latrines are suitable for small villages and country districts where there is room to make the latrines at some distance from houses. In larger villages and towns it is often necessary to collect the excreta and remove it for proper disposal. Under such conditions, the latrines are usually provided with buckets to receive the excreta (see Fig. 95). A small quantity of disinfectant is sometimes put in the bucket, and

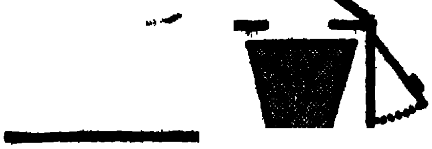


FIG. 95.—Simple bucket latrine

it is a good practice for the user to cover the faeces with a little dry earth to exclude flies. These buckets are removed (preferably in the early hours of the morning) into carts, or, better still, the bucket is replaced by a clean one and is removed in a special lorry fitted with closed compartments. Such a system is expensive and requires very careful planning and supervision if it is to be satisfactory, e.g. it is often difficult to find labourers for this unpleasant job, and since the work is usually done before daybreak, supervision is difficult in the dark.

The excreta (or 'night-soil') collected in the buckets are usually disposed of by dumping or *trenching*. The trenching-ground should be at least half a mile away from the town or village, and the soil should be porous and well drained. Long, narrow trenches are dug, about 18 in. wide and 12–18 in. deep and about 18 in. apart. A layer of excreta, 3–6 in. deep, is put in the trench and then covered with earth. Under favourable conditions, decay is complete in a few months, but crops are not usually grown there for a year.

In some towns it is possible to empty the night-soil from bucket latrines into the sewers leading to a sewage-disposal works.

A very sanitary method for disposing of night-soil is to burn it in a specially-designed incinerator, after mixing with dry refuse or other material. Unless plenty of dry refuse is at hand, however, incineration is very costly.

In some tropical countries, house and town refuse and excreta are disposed of by *composting*. This method has the practical advantage that it yields a product which is of great value as a manure for crops. Organic refuse is mixed with excreta and then left standing in a heap for about a week. Owing to the action of bacteria, the mixture soon gets hot, reaching a temperature of 140°–160° F. in the middle of the heap. At this temperature, any disease-producing bacteria and the eggs of intestinal worms are killed, and flies cannot breed. The compost heaps are turned at weekly intervals to admit air and to transfer the outer layer to the middle of the heap where it will become hot enough to kill unwanted organisms. The compost is ready for use as manure in about two months.

Septic tanks

When sewage (i.e. excreta mixed with waste water) is run into a closed tank, it is decomposed by bacteria which grow and multiply in the absence of oxygen. Large volumes of harmless gases are produced and the solid faeces are broken up. A thick scum forms on the surface of the liquid, and mud settles to the bottom of the tank. This mud and scum must be removed occasionally (about once or twice a year). The liquid from the *septic tank* overflows on to a filter-bed of loosely-packed broken stone, where it is acted upon by bacteria which flourish in the presence of oxygen (see Fig. 96). The ammonia produced by the decomposition of protein material in the septic tank is finally oxidized to nitrates, and the liquid which flows out of an efficient septic tank and filter-bed is harmless and free from smell. As a further safeguard, this liquid is sometimes allowed to run down an open concrete drain exposed to air and sunlight. The design and construction of septic tanks requires expert knowledge.

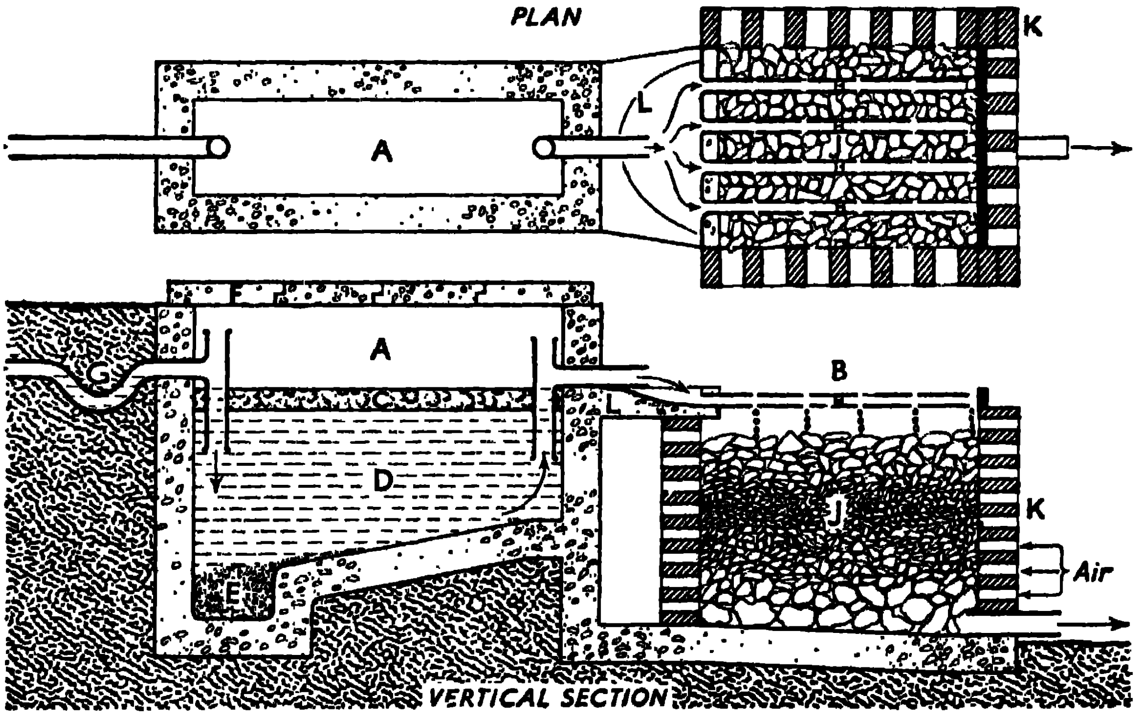


FIG. 96.—Septic tank and aerating filter-bed

A—Closed tank. B—'Filter' for oxidizing product from closed tank. C—Layer of scum excluding air. D—Sewage. E—Deposit of mud. F—Close-fitting covers for inspection and cleaning. G—Water-seal on inlet to prevent back-flow of gases. H—Distributing channels with loose-fitting joints. J—Loosely packed stone, forming 'filter-bed'. K—Walls of 'honeycomb' brickwork to admit air to 'filter-bed'. L—Distributor.

When properly constructed and used so as to provide proper conditions for bacterial action, a septic tank does not produce unpleasant smells, because the bacteria in the closed chamber digest the solid matter in the sewage and destroy the harmful bacteria it contains. It is important *NOT to add antiseptics or disinfectants* to sewage which is to be treated in a septic tank, for this will destroy the useful bacteria present in the septic tank and upset its working, causing it to fill up too quickly with mud, thus blocking the outlet. Soap and grease have a similar action in checking the action of the useful bacteria, hence it is better to dispose separately of waste water from the kitchen and wash-place.

Cess pools are sometimes used for sewage disposal because they are easy to construct, but they are not satisfactory. A cess pool is simply a deep hole in the ground lined with loose bricks or stones through which the liquid sewage soaks into the surrounding earth. There is no purifying bacterial action, and the cess pool quickly fills up with solid matter and has to be cleaned out at frequent intervals. The bad smell from a cess pool is a nuisance and the drainage from it is a danger to any water supply in the neighbourhood.

Water-carriage sewerage systems

A septic tank is the simplest example of the water-carriage system of disposal since the faeces are carried to the tank by the water which is used to wash down the squat-pan after use. The largest septic tanks, however, will only meet the needs of small communities of a few hundred people. For larger communities, e.g. modern towns and cities, the excreta, together with all waste water from washing and cooking, flow through drainpipes (called *sewers*) to *sewage-disposal works*. In most towns, rain-water from house and street drains also enters the sewers. Hence the sewage flowing through the pipes in a water-carriage system is mainly water (about 99·9 per cent.) carrying suspended and dissolved matter (about 0·1 per cent.). At the sewage-disposal works the sewage passes through metal netting screens to remove any large solids, and then through tanks where the denser suspended mineral matter (e.g. dirt washed off roads, and sand used for cleaning cooking-vessels) settles to the bottom, while the less dense suspended organic matter passes on for treatment in the *settling-tanks*. The sewage flows very slowly through these settling-tanks so that the small, light particles of organic matter settle as mud before reaching the outlet. The liquid which runs out of the settling-tanks is further purified through oxidation by bacteria as it drips slowly over loosely-packed stone filters (as in the septic tank system) and is then discharged into a river or the sea.

The most difficult problem of sewage-disposal is how to deal with the organic mud left in the settling-tanks. One of the best methods is to allow the mud to be decomposed by bacteria, first in closed vessels and then in open vessels, for several weeks. The product has no smell and can be dried and used as a manure for crops.

REFUSE DISPOSAL

House refuse in tropical countries usually contains much damp vegetable matter which decays rapidly at such high temperatures, producing an unpleasant smell. It also provides food for rats and a breeding-place for flies. Hence it must be disposed of quickly—every day, if possible—before it becomes a nuisance.

People living outside towns and large villages usually have to deal with their own house refuse, and the best method is to burn it each day, using a simple *incinerator*. This can be made out of an old oil-drum by cutting openings in the bottom and sides so as to admit plenty of air. The drum should be raised above the ground on bricks or stones and sheltered from the rain by a sheet of galvanized iron supported on a raised framework. A fire is started with dry material and the refuse is then added.

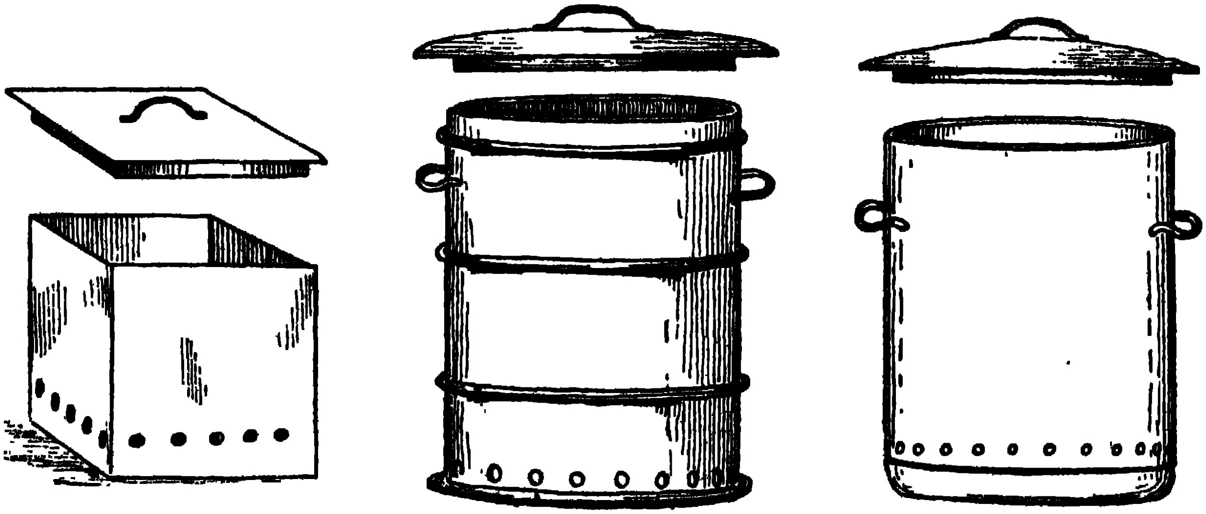


FIG. 97.—Sanitary dust-bins

In towns and large villages, house refuse and street sweepings are collected and removed by the sanitary authorities. House refuse should be put into covered metal *dustbins*, which should be rat-proof and fly-proof (see Fig. 97). In tropical countries, this refuse should be collected every day, if possible, the dustbins being emptied into covered carts or lorries. There are several methods for disposing of the refuse after collection, the commonest being (*a*) *burning* and (*b*) *dumping*.

(*a*) *Burning*. This is the best method because the refuse is made harmless, but since house refuse in tropical countries usually contains a lot of wet vegetable matter it can only be burnt in properly designed incinerators or *destructors*. It is sometimes necessary to dry the refuse for a few hours before it will burn.

(*b*) *Dumping*. House and town refuse is sometimes used for filling up hollows and for raising the level of low-lying land. Unless great care is taken, this method gives rise to unpleasant smells, while the rubbish-dumps attract rats and become breeding-places for flies; hence refuse should never be dumped near houses. The refuse should be spread out in layers only a few feet thick and each layer of refuse should then be covered with a layer of earth, at least one foot thick, as soon as possible. This excludes air so that suitable bacterial action raises the temperature sufficiently to destroy harmful organisms and break down the animal and vegetable refuse into harmless material. Land levelled in this way can be used after a few years for playing-fields, but it should not be used for building-land.

HOUSING

We have learnt that Man's principal material needs are for *food, clothing*, and *shelter*. We shall now consider the last-named need, and how the health and comfort of people living in tropical countries are affected by their housing conditions.

The minimum housing accommodation needed in the tropics is (*a*) a room for shelter and sleeping, (*b*) a back verandah for housework and cooking, (*c*) a front verandah for social life, (*d*) a small lock-up store, (*e*) a bathing-place and a place to wash clothes, (*f*) a covered place to keep dry firewood, (*g*) a latrine, and (*h*) an incinerator for burning rubbish.

Floors should be of hard material which does not wear readily to form dust, and they are easier to keep clean if not covered with mats, rugs, or carpets. In the same way, plain wood or cane furniture is better suited to tropical conditions than the padded and covered furniture commonly used in colder climates.

It is important that the site chosen for building a house should be well drained, so that it does not become marshy and malarial in wet weather. If no alternative position is available, then the house should be raised above the ground on pillars and the earth under the house should be covered with concrete, if possible. In general, houses built on higher ground are drier and cooler since they catch more breeze. If possible the bedrooms should not be on the west side of the house, otherwise they become heated by the afternoon sun and remain hot for some time after sunset. A house should be surrounded by an open space to allow free movement of air round and through the house. A garden with small trees and plants will make the house cooler and a pleasanter place to live in, but large trees should not be allowed to overhang the house. Care should be taken that the trees have no holes in which rain-water collects. If it does, the holes should be filled with concrete. Bamboo often retains water and breeds mosquitoes in its hollow stems where branches have been cut or broken off.

Bricks, stone, and concrete are the best materials for building the walls, although wood and galvanized iron are often used. If wood is used, it should either be 'hard wood' or treated with chemicals to keep out termites ('white ants'). A 'damp-proof' layer should be laid in all brick or stone walls about 6 in. above ground level. This consists of a waterproof layer of pitch, zinc, or glazed brick, to stop water rising through the wall by capillarity. Sheets of galvanized iron are sometimes used for this purpose, with the outer edge extending outside the building so as to stop rats from climbing up the walls. If the walls are whitewashed outside, they will absorb less heat from the sun.

Verandahs help to keep houses shady and cool, but they should be at least 10 ft. wide if they are to protect the house-walls from the direct rays of the sun. There should be enough window-space to let in plenty of light and air, and it is a great advantage to have window-openings on two opposite sides of every room to allow a through current of air for ventilation. Inside walls should be painted or colour-washed in light colours. A badly-lighted and badly-ventilated room with dark-coloured walls will tend to become dirty because it is so difficult to see the dirt.

The commonest roofing materials are thatch, tiles, and galvanized iron. Thatch is cheap and cool, but it may shelter rats and insects, and there is also danger from fire in dry weather. If covered with fine wire-netting, however, thatch can be made rat-proof. Tiles are a very satisfactory roofing material, but they should be properly laid so as to leave no nesting-places for rats. Galvanized iron is cheap and easily fixed in place, but an iron roof is very hot in the daytime unless properly ventilated, e.g. with a ridge-ventilator. A wood or asbestos ceiling below the iron roof makes the house much cooler, particularly if sheets of thin, polished, aluminium foil are laid on top of the ceiling to reflect back the heat. Rain-water channels round the edges of a roof may be dangerous in tropical countries because they may hold water in which mosquitoes can breed. Channels are necessary where rain-water has to be stored for domestic use, but care should be taken that they do not become blocked up, e.g. with dead leaves, and that they do not bend between the supports. If it is not necessary to collect the rain-water, it is safer to do without channels round the lower edge of the roof, and to allow the rain to drip direct into a concrete drain surrounding the whole building. In order to throw the rain-water clear of the outer walls, the roof should continue at least 2 ft. beyond them.

When there is a plentiful supply of water for domestic purposes, special arrangements are necessary for getting rid of used water. In large villages and towns there is usually a system of street drains into which house-drains discharge. Where houses are far apart and where there are no public drains, then a *soak-pit* may be used to receive waste water from kitchen, bathing-place, and wash-place. This water flows through drain-pipes into a long narrow pit, dug in lower ground some distance from the house and packed with broken stone or similar material. The waste water gradually soaks away into the surrounding soil, well away from the house. A roof of concrete slabs, covered with earth and grass, hides the pit and prevents mosquitoes from breeding in it.

In towns, no building may be built or any change made in it until the plans have been inspected and approved by the public health authority. This ensures that houses shall be properly built and free from dampness, that the rooms are large enough, well lighted, and well ventilated. There must also be proper water supply, drains, and latrines. Some countries have Town Planning Departments to see that towns are arranged so as to be healthy places to live in. Certain areas are usually reserved for dwelling-houses, and other areas for factories. Public gardens, parks, and playing-fields are planned so that every citizen is within easy reach of an open space for exercise. The road system is carefully planned so that it is easy to get from one part of the town to another, and also so that light and air reach every building. Town-planning also provides for re-housing people living in the older, crowded parts of the town, under unhealthy conditions, by building new houses in better situations.

FOOD PURITY

The public health service also looks after the purity of the food supply by controlling and inspecting markets, abattoirs, bakeries, dairies, and any other places used for the preparation, sale, or storage of food.

People that produce their own food from farms and gardens can control its cleanliness for themselves, but in many modern communities people cannot produce their own food supply and have to depend on others for it. Under such conditions, the user seldom knows how the food was grown, stored, and handled before he buys it in the shop or market, so in well-organized communities the public health service controls the handling and distribution of food (including milk).

Sanitary inspectors have authority to take a sample of any foodstuff offered for sale and to send it to the laboratory for examination. They pay particular attention to the inspection of meat and milk, including the methods of producing and distributing the latter. Some sanitary authorities also examine dairy animals for signs of tuberculosis.

To protect the health of the community, all civilized countries have *pure food laws* providing punishments for those people who try to sell inferior or contaminated food.

The public health department also controls food markets, seeing that the stalls are properly constructed and washed down with plenty of clean water at frequent intervals. Market inspectors also see that waste matter is properly disposed of, so as to keep the market and its surroundings free from rats and flies.

CONTROL OF INFECTIOUS DISEASES

In most tropical countries people are obliged by law to report to the public health authorities any cases of infectious diseases, e.g. plague, cholera, smallpox, chicken-pox, diphtheria, measles, and typhoid. The health authorities then arrange for the isolation of the patients and for the disinfection of houses and their contents. People who have been in contact with the patients are isolated or kept under observation, while the health authorities also try to discover the original source of the infection and to deal with it, Vaccination against smallpox is usually compulsory and is carried out by the public health authorities. The compulsory muzzling of dogs to prevent the spread of rabies is also organized by the public health authority. Special care is taken at sea-ports and border stations to prevent the entry of infectious diseases from foreign countries. If a ship arrives with cases of infectious disease (e.g. cholera, plague, or smallpox) on board, or arrives from an infected port, the port health authority has the ship disinfected and keeps the passengers in quarantine until it is known that they are free from infection. In tropical countries, the public health service is largely concerned with preventing the spread of malaria, mainly by anti-mosquito work and free treatment with drugs.

REGISTRATION OF BIRTHS AND DEATHS—VITAL STATISTICS

Just as commercial book-keeping shows the state of a business, so *vital statistics* reflect the state of health in a community. In order to measure the effect of public health work, most countries make it compulsory to register births and deaths. For example, if the number of deaths per thousand people in a district is much higher than usual, then the public health authorities look for the cause. Since it is necessary on registration to state the cause of death, the health authorities can tell which diseases are being controlled and which need better preventive measures. Registration of births and deaths also enables the public health authorities to measure the *infant death-rate*, i.e. the proportion of babies who die before they are one year old. Since most of these infant deaths are preventable, the infant death-rate is a very good guide to the local health conditions—the lower the infant death-rate the healthier the district.

INFANT WELFARE AND SCHOOL MEDICAL SERVICES

The aim of these public health services is to check the beginnings of ill-health in young children. Many grown-up people suffer ill-health because small defects were not treated when they were children. If every school-child is examined once a year by a doctor and a dentist, these small defects can be discovered and can receive skilled treatment. Many young children suffer from health defects before they begin going to school, and Infant Welfare Centres aim at making children healthy in the first few years of their lives. Since a baby's health in its youngest days depends on its mother, most countries have health centres where mothers can get skilled advice about their own health and that of their babies.

PUBLIC HEALTH EDUCATION

Public health work can only succeed through willing and understanding co-operation by members of the community who understand the reasons which underlie the study and practice of hygiene. This health education, as a part of the ordinary education of every boy and girl, should consist not merely in learning facts about personal health, but also practical training in the habits of healthy living. Many people who have been 'taught hygiene' at school may understand the subject from the scientific point of view and pass written examinations in hygiene without *using* the principles which they have learned to acquire and maintain good health for themselves. Although the public health authorities can compel people by law to carry out certain health measures, they are always unwilling to make use of such powers. Willing and understanding co-operation is much better than compulsion, and if the author has helped to prepare you to co-operate in this way after you leave school then this book will have realized its main aim.

APPENDIX A

FOOD TABLES

The food tables that follow are designed to help in planning practical everyday diets with natural foods that are commonly available in tropical countries. Table I summarizes the daily nutritional requirements of people of varying age, sex, and occupation. Tables II–VIII provide a guide to the selection of suitable protective foods. The teacher should also have available at least one copy of a complete set of tables showing the composition of commonly used foods, e.g. B. S. Platt, *Tables of Representative Values of Foods Commonly Used in Tropical Countries* (Medical Research Council, Special Report Series No. 253. Published by Her Majesty's Stationery Office at 1*s*. 6*d*.). Most of the figures given in Tables II–VI have been taken from this source.

TABLE I

DAILY NUTRITIONAL REQUIREMENTS

The following recommendations are based on the scientific knowledge of 44 nations represented at a United Nations Food Conference. They have been used all over the world as a guide in nutritional work.

(The letters in brackets refer to the footnotes.)

						Vitamin B			Vitamin C	
	Calories (*a*)	Protein (gm.)	Calcium (gm.)	Iron (mg.)	Vitamin A (*b*) (I.U.s)	Thiamine (*c*) (mg.)	Riboflavin (*c*) (mg.)	Nicotinic Acid (*c*) (mg.)	Ascorbic Acid (mg.)	Vitamin D (I.U.s)
MAN (156 lb. = 70 Kg.)										
Sedentary occupation	2500	70	0·8	12 (*d*)	5000	1·2	1·6	12	75	(*e*)
Moderately active .	3000	70	0·8	12 (*d*)	5000	1·5	2·0	15	75	(*e*)
Very active	4500	70	0·8	12 (*d*)	5000	2·0	2·6	20	75	(*e*)
WOMAN (125 lb. = 56 Kg.)										
Sedentary occupation	2100	60	0·8	12	5000	1·1	1·5	11	70	(*e*)
Moderately active .	2500	60	0·8	12	5000	1·2	1·6	12	70	(*e*)
Very active . . .	3000	60	0·8	12	5000	1·5	2·0	15	70	(*e*)
Pregnant	2500 (*f*)	85	1·5	15	6000	1·8	2·5	18	100	400–800
Lactating	3000	100	2·0	15	8000	2·0	3·0	20	150	400–800
CHILD (up to 12 years) (*g*)										
Under 1 year (*h*) . .	100/Kg.	3·5/Kg.	1·0	6	1500	0·4	0·6	4	30	400–800
1–3 years (29 lb. = 13 Kg.) .	1200	40	1·0	7	2000	0·6	0·9	6	35	400
4–6 years (42 lb. = 19 Kg.) .	1600	50	1·0	8	2500	0·8	1·2	8	45	400
7–9 years (55 lb. = 25 Kg.) .	2000	60	1·0	9	3500	1·0	1·5	10	60	400
10–12 years (75 lb. = 34 Kg.) .	2500	70	1·2	10	4500	1·2	1·8	12	75	400
GIRL (over 12 years) (*g*)										
13–15 years (108 lb. = 49 Kg.) .	2600	80	1·3	15	5000	1·3	2·0	13	80	400
16–20 years (119 lb. = 54 Kg.) .	2400	75	1·0	15	5000	1·2	1·8	12	80	400
BOY (over 12 years)										
13–15 years (103 lb. = 47 Kg.) .	3200	85	1·4	15	5000	1·5	2·0	15	90	400
16–20 years (141 lb. = 64 Kg.) .	3800	100	1·4	15	6000	1·8	2·5	18	100	400

(*a*) All these figures show what to aim at in planning practical diets with natural foods. Such a diet will also provide other mineral salts and vitamins whose precise requirements are less fully understood.

(*b*) This requirement depends upon the relative amounts of Vitamin A and carotene. The figures in the table assume that approximately two-thirds of the Vitamin A allowance comes from carotene and that carotene has about half the protective value of Vitamin A.

(*c*) For adults (except pregnant and lactating women) on diets supplying 2,000 Calories or less, the allowance of thiamine, riboflavin, and nicotinic acid may be 1 mg., 1·5 mg., and 10 mg. respectively. The fact that different figures are given for thiamine, riboflavin, and nicotinic acid for different Calorie levels does not mean that we can estimate the requirement of these accessory food factors so closely, but they are given merely to make calculation easier. Other vitamins of the B group are also required, although no precise figures can be given in the table, but a diet supplying sufficient thiamine, riboflavin, and nicotinic acid will usually supply adequate amounts of the other B-group vitamins.

(*d*) There is now evidence that the adult *male* needs less iron than was formerly believed to be necessary. If the diet is satisfactory in other respects there will also be sufficient iron.

(*e*) Adults who are seldom exposed to clear sunshine may need small amounts of Vitamin D. Other *adults* need very little Vitamin D in the tropics.

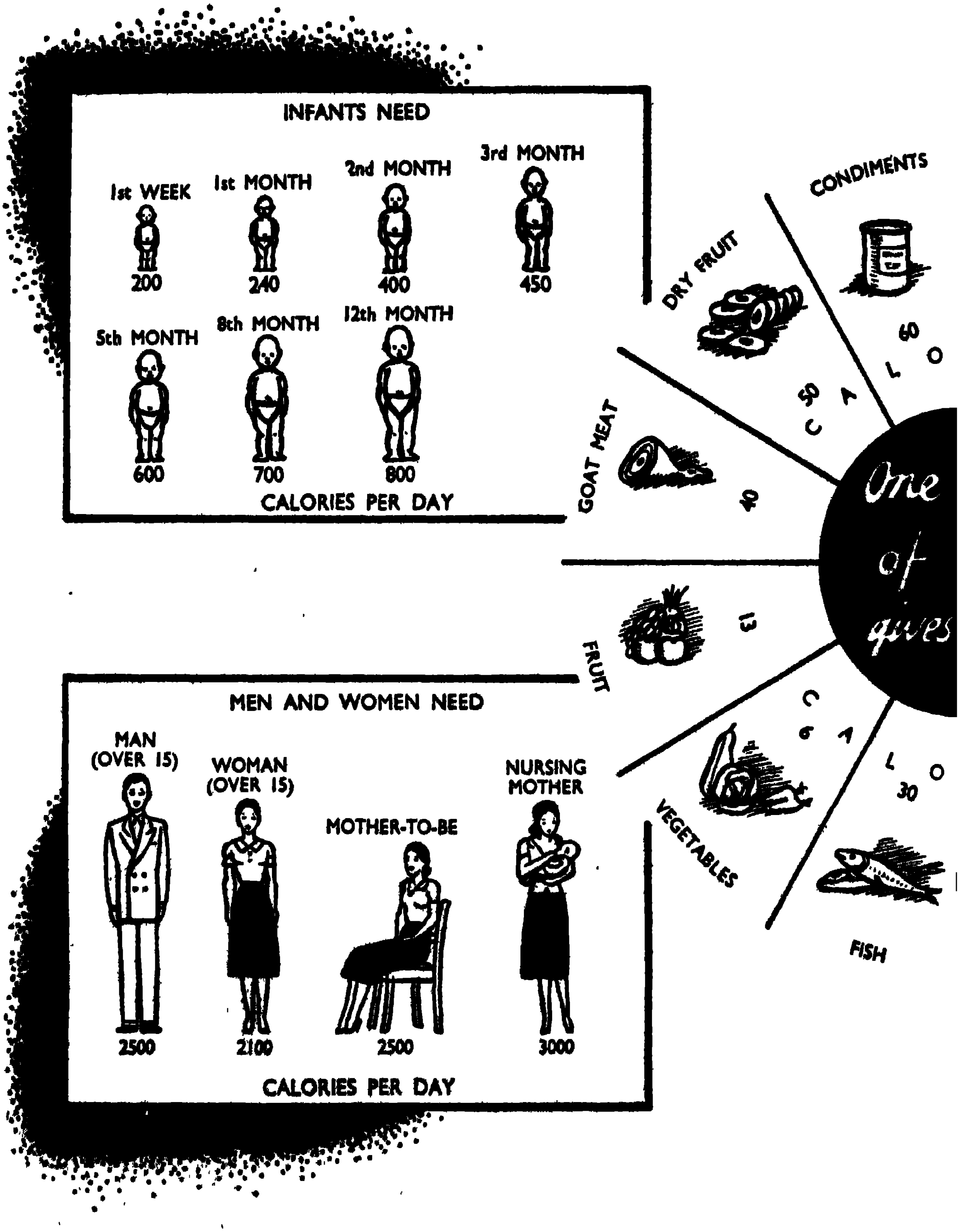
(*f*) During the latter part of pregnancy the Calorie allowance should be increased by about 20 per cent. The value of 2,500 Calories given in the above table is for pregnant women engaged in *sedentary* occupations.

(*g*) These children's requirements are based on the needs of the middle year in each age-group (i.e. 2 yrs., 5 yrs., 8 yrs., &c.) and are for moderate activity and for average body-weight at the middle year of the age-group.

(*h*) The needs of infants (under 1 year) increase from month to month with size and activity. The figures given are for infants of 6–8 months. Requirements of some nutrients (e.g. protein and calcium) are less if they are supplied largely in the form of human milk.

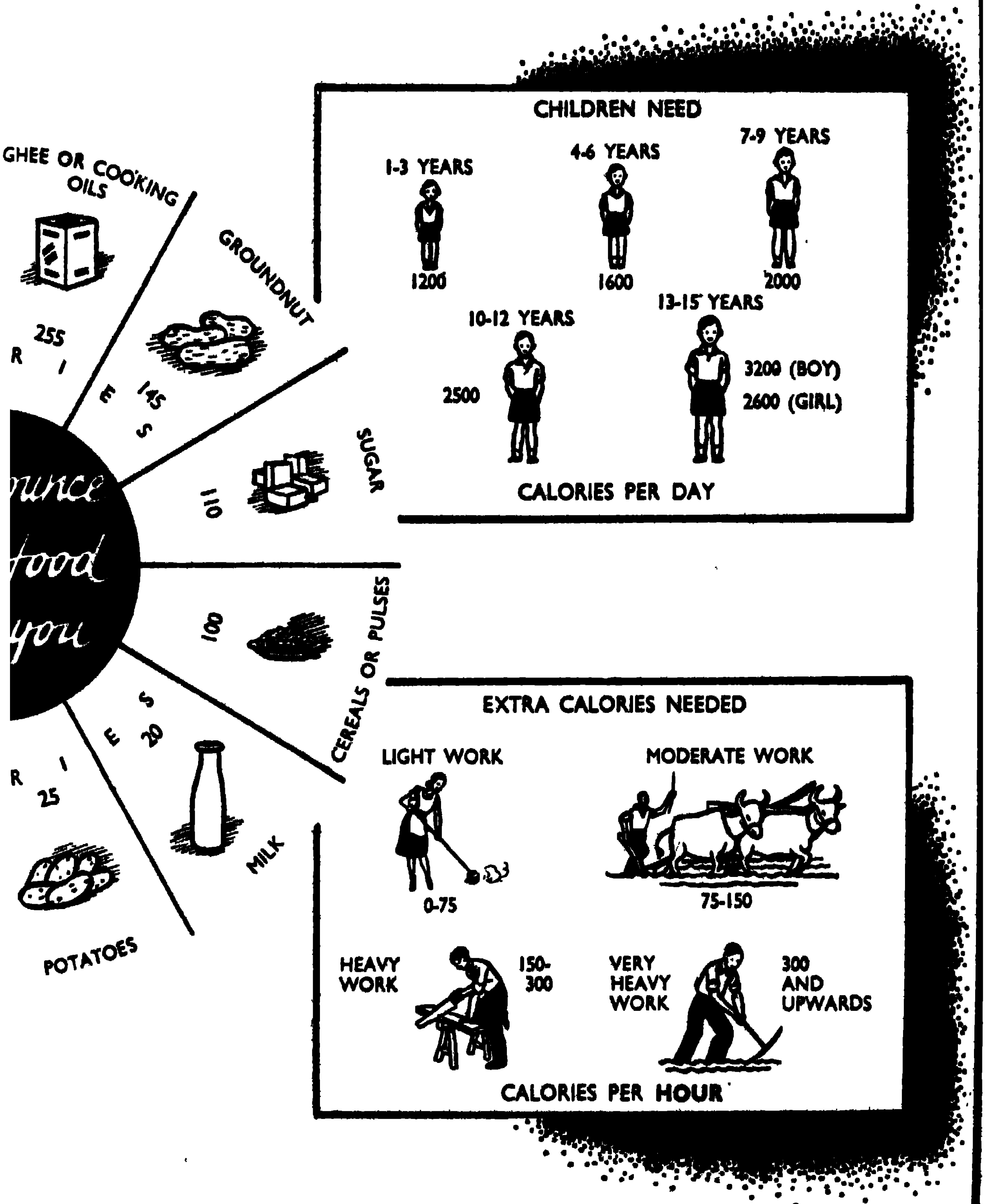
CALORIE

TAKE A PENCIL AND PAPER AND WITH THE HELP OF THIS CHART TRY TO



CHART

VORK OUT WHETHER YOUR OWN MEALS SUPPLY YOUR CALORIE NEEDS



SPECIMEN DIET FOR MODERATELY ACTIVE MAN

Food groups	Approx. daily requirements (ozs.)	Approx. No. of Calories
Green, leafy vegetables (rich in vitamin A and iron)	4	52
Root vegetables like potatoes and sweet potatoes (high carbohydrate content, significant vitamin C contribution) and other vegetables	6	60
Pulses, dry beans and peas, and nuts (valuable for high protein and thiamine content)	3	300
Fruits (well-balanced mineral content and vitamin values)	3	54
Cereals and products (excellent source of energy, good source of protein and some 'B' vitamins, also minerals), cereals, restored or whole-grain bread, enriched or whole-grain flour . . .	14	1400
Milk and its products other than butter (important for protein, calcium, and riboflavin)	10	330
Eggs (for protein, iron, and vitamin A)	1	86
Meat, fish, and poultry (rich sources of protein with minerals and moderate amounts of several of the 'B' vitamins)	3	120
Ghee, vegetable oils, and other fats (for energy; butter and ghee are also sources of vitamin A)	2	500
Sugar, jaggery, and sweets (for energy) .	2	224
Total essential needs (approximately) 3,000 Calories		Total 3126

TABLE II

FOODS RICH IN VITAMIN A

(For daily requirements of vitamin A see Table I)

The figures given below indicate the number of *International Units present in 100 grams of edible material.* (In the case of fruits and vegetables and any other foods containing both vitamin A and carotene, the 'vitamin A value' includes an allowance for the carotene they contain, since carotene is converted into vitamin A in the body.)

ANIMAL PRODUCTS	
Liver	27000
Kidney	1000
Eggs	1000
Milk, cow's, fresh	100–140
Milk, condensed, sweetened	400
Milk, condensed, unsweetened, evaporated	400
Milk, dried, whole	1400
(Milk, dried, skimmed	60)
Butter	2700
Ghee (clarified butter)	2500*
Cheese	1400

PLANT PRODUCTS	
Papaya (Pawpaw)	2500
Tomato	1200
Mango	1000
Banana	350
Pineapple	200
Orange	250
Red Palm Oil	40000–80000
Carrot	13000
Sweet Potato, root (*red*)	7000
Green Leafy Vegetables[1]	13000
Beans, eaten green in pod	600
Beans and Peas, eaten green, shelled	400
Betel leaves	9500
Onion, young, eaten with leaf	3000
Lettuce	2000
Leek	700
Cucumber	200
Ladies' Finger (Okra)	1000
Pumpkin (Squash) yellow	1100
Peppers, green, fresh	1000
Peppers, red, fresh	18000

Foods lacking in vitamin A value

Cereals. Salt fish. Beef. Mutton. Pork. Poultry. Vegetable fats and oils (except Red Palm Oil). Margarine.[2] Goat fat. Pig fat (including bacon-fat). Lard. Skimmed milk.

* May be much lower, depending on the method of preparation.

---

[1] e.g. Dark green leaves of spinach (Amaranth), sweet potato, mustard, cassava, pumpkin, cow-pea.

[2] Some margarine contains added vitamins A and D.

TABLE III

FOODS RICH IN VITAMIN B_1

(For daily requirements of vitamin B_1 see Table I)

The figures given below indicate the number of *milligrams of vitamin B_1* (thiamine or aneurin) *present in 100 grams of edible material.* Low-value products are shown in brackets for comparison.

PLANT PRODUCTS	
Rice, brown, lightly milled	0·24
(Rice, white, polished	0·06)
Rice, parboiled	0·21
Rice Polishings	1·2
Rice Bran	0·5
Maize, whole grain, yellow	0·33
Maize Meal, whole	0·3
(Maize Meal, highly refined	0·05)
(Maize Starch, 'cornflour'	0·00)
Maize, sweetcorn, green mealies	0·15
Millet, bulrush	0·5
Millet, finger	0·28
Oatmeal	0·5
Rye Flour	0·27
Sorghum	0·5
Wheat, whole grain	0·4
Wheat Flour, wholemeal, atta	0·3–0·4
Wheat Flour, white	0·06
(Arrowroot	0·00)
Potato, English/Irish	0·1
Potato, sweet	0·1
Bambara Groundnut	0·3

PLANT PRODUCTS (*cont.*)	
Cowpea	0·9
Groundnut (pea-nut), dry	0·9
Kidney Bean (French Bean)	0·45
Lentil (red dhall)	0·65
Lima bean (Butter Bean)	0·53
Grams, red, yellow, green and black	0·45
Soya Bean	1·12
Sesame (gingelly) seed	0·42
Yeast, baker's	3
Yeast, brewer's	16
Yeast, food	2

ANIMAL PRODUCTS	
Pork, lean, fresh	1
(Beef	0·09)
Eggs	0·14
Mutton, sheep, or goat	0·20
Poultry	0·15
(Milk, cow's	0·04)
(Cheese	0·04)
(Fish	0·05)

Foods lacking in vitamin B_1

White, polished rice, and other 'refined' cereal products, e.g. white flour and white bread. Cassava (tapioca) flour. Meat (except pork). Fish. Milk and cheese.

TABLE IV

FOODS RICH IN VITAMIN C

(For daily requirements of vitamin C, see Table I)

The figures given below indicate the number of *milligrams of vitamin C* (ascorbic acid) *present in 100 grams of edible material.*

PLANT PRODUCTS

Fruits, fresh	
Guava	200
Indian Gooseberry	600
Lime	25
Orange	45
Passion Fruit (Grenadilla)	20
Papaya	30
Melon, sweet	35
Avocado Pear	20
Cape Gooseberry	30
Pineapple	30
Tomato	25
Banana	10

Vegetables, fresh [1]	
Green Leafy Vegetables [2]	100
Persimmon Leaves, fresh	2700
Persimmon Leaves, dried	3500

Vegetables, fresh	
Peppers, sweet, green	200
Peppers, sweet, red	350
Beans, eaten green in pod	20
Beans and Peas, eaten green, shelled	25
Ladies' Finger (Okra)	25
Onion, young, eaten with leaf	20
Leek	20
Cassava (tapioca), tuber	30
Potato, English/Irish	15
Potato, sweet	20
Maize, sweetcorn, green mealies	10

Foods lacking in vitamin C value

Cereals and cereal products. Most starchy roots. Most dried fruits and vegetables. Dried peas and beans. Meat. Eggs. Milk. Jam. Green vegetables *cooked with soda.*

---

[1] Vitamin C value much reduced by cooking.

[2] e.g. dark green leaves of spinach (Amaranth), sweet potato, mustard ,cassava, pumpkin, and cowpea.

NOTE ON VITAMIN D REQUIREMENTS

No separate table is given here to show foods rich in vitamin D (calciferol) since many of the foods listed in Table II as good sources of vitamin A also supply vitamin D, e.g. animal fats like fat meat, fat fish, eggs, milk and butter. Also, as mentioned on p. 68, green leaves contain small quantities of ergosterol, which can be converted into vitamin D in the human body, so that if the diet includes sufficient green leafy vegetables then the vitamin D requirement will also be satisfied (provided that the skin gets some sunlight). Serious vitamin D deficiency can be remedied by the use of fish-liver oils and by the use of yeast-extracts that have been exposed to ultra-violet light.

TABLE V

FOODS RICH IN IRON

(For daily requirements of iron, see Table I)

The figures given below indicate the number of *milligrams of iron present in 100 grams of edible material.*

PLANT PRODUCTS	
Yeast	20
Coriander, seed	18
Mustard, seed	18
Turmeric, root, dry	18
Sesame (gingelly), seed	15
Fenugreek, seed	14
Cocoa, powder	14
Tamarind	11
Job's Tears (adlay)	10
Grams	4–9
Kidney Bean	8
Sorghum	7
Soya Bean	7
Lentils (red dhall)	7
Molasses	7
Betel leaves	6
Wheat	3–5
Maize	5
Millet	5
Oatmeal	5

ANIMAL PRODUCTS	
Liver	10
Kidney	10
Heart	8
Shellfish	5

TABLE VI

FOODS RICH IN CALCIUM

(For daily requirements of calcium, see Table I)

The figures given below indicate the number of *milligrams of calcium present in 100 grams of edible material.*

PLANT PRODUCTS	
Sesame (gingelly) seed	1500
Cumin	1080
Coriander	630
Mustard, seed	490
Millet, finger	350
Soya Bean	220
Grams	140–280
Job's Tears (adlay)	200
Molasses	270
Green Leafy Vegetables	210
Tamarind	170
Betel leaves	150
Food Yeast	127
Kidney Bean	110

ANIMAL PRODUCTS	
Milk, powder, skimmed	1200
Milk, powder, whole	900
Milk, condensed	240–290
Milk, cow's fresh	120
Cheese	850
Eggs	55

NOTE ON PHOSPHORUS REQUIREMENTS

No separate table is given here for foods rich in phosphorus because most of the foods listed opposite as being rich in calcium are also rich in phosphorus. So if the daily calcium requirement is satisfied from these sources it is almost certain that the body will get sufficient phosphorus at the same time. Also, it is better to have an excess of calcium in the diet than to have an excess of phosphorus (for reasons explained on p. 57) and you can ensure that your phosphorus intake will be adequate by looking after your calcium intake.

TABLE VII

FOODS RICH IN PROTEIN

In comparing the food-value of protein foods it is necessary to know what proportion is digested and absorbed. The first column shows the total amount of protein as determined by chemical analysis; the second column shows what percentage of this protein is available to the body after digestion*; the third column shows what percentage of the original food actually supplies protein to the body.

	Total protein present in food. (per cent.) (*a*)	Relative availability (per cent.) (*b*)	Percentage actually available (*a* × *b*)
Soya Bean	43	54	23
Beef (lean)	22	98	22
Peanuts (roast) . . .	32	56	18
Peanuts (raw) . . .	28	58	16
Pulses (dried). . . .	26	50	13
Eggs	12	94	12
Rice (brown)	11	80	9
Rice (white)	6	80	5
Wheat Flour	11	67	7
Maize (whole) . . .	11	60	7

Notice (*a*) that the animal proteins in the above list are almost completely utilized by the body; (*b*) that the vegetable proteins are of much lower biological value, weight for weight; (*c*) that the protein in rice is of higher biological value than that of other cereals; (*d*) the very high value of the soya bean as a protein food.

---

* i.e. the *biological quality* of each particular protein.

TABLE VIII

AVERAGE COMPOSITION OF MILK OF VARIOUS MAMMALS

Animal	Water (per cent.)	Fat (per cent.)	Milk Sugar (per cent.)	Protein (per cent.)	Mineral matter (per cent.)
Human Females . . .	87·6	3·8	6·4	2·0	0·3
Cow (European) . . .	87·4	3·8	4·8	3·4	0·8
Cow (Indian)	86·7	4·3	4·7	3·7	0·8
Buffalo	82·2	7·7	4·8	4·4	0·9
Goat	86·9	4·1	4·6	3·8	0·9
Sheep	83·6	6·2	4·2	5·2	1·0
Ass	90·1	1·4	6·2	1·9	0·5
Elephant	79·3	9·1	9·0	2·5	0·5

APPENDIX B

PRACTICAL WORK

(NOTE FOR TEACHERS—If *Health Science* is to justify its name it must be taught as a science subject with adequate experimental and practical work. The following instructions for carrying out practical work have been collected together at the end of the book in order to allow a more continuous text in the foregoing chapters. For further information about dissection, physiological experiments, preparation of reagents, &c., see the Teachers' Handbook to *General Science for Tropical Schools* by the same author.)

DISSECTION OF A MAMMAL

Students will get a much clearer idea of the structure of their own bodies if they see a small mammal dissected. Rabbits, rats, or guinea-pigs are very suitable for this purpose and the following instructions are intended to guide the teacher in carrying out such a dissection. These instructions apply particularly to the guinea-pig (which is very easy to rear and keep in captivity), but other small mammals may be dissected by the same method. The demonstrator should have 3 scalpels (large and small), 2 pairs of forceps (large and small), 2 pairs of dissecting scissors (large and small), 2 mounted needles, 1 seeker (blunt). (In cases where the teacher is unable to carry out the dissection himself it is often possible to arrange for a biologist or a medical student to visit the school and dissect a small mammal in front of the class.)

External characters

(I) Watch the movements and examine the external characters of living mammals, e.g. cats, dogs, rats, mice, rabbits, or guinea-pigs. The animal is *sensitive* and responds quickly to a *stimulus*. Notice the movable external ears, the wide range of vision, the whiskers and eyebrows (which are organs of touch). Watch the animal feeding and notice that the lower jaw is freely hinged and can move up and down; in gnawing mammals, like the rabbit, the lower jaw can also be moved slightly from side to side and from back to front.

(II) Examine a guinea-pig which has been freshly killed with chloroform.

Notice (i) that the body is covered with *hair* and (ii) that the body is divided into distinct body-regions—*head*, *neck*, *trunk*, and *limbs*. (The neck is more clearly marked in many other mammals.)

Examine the *head* and notice (*a*) the *mouth*, with a pair of soft lips, the upper lip being slit down the middle, connecting the mouth with the *nostrils* and exposing the sharp-edged gnawing teeth (or *incisors*). Inside the mouth notice that the teeth are fixed in sockets in the jaw-bone and that they are of two main kinds: gnawing teeth (incisors) and grinding teeth (*molars* and *pre-molars*). The roof of the mouth in front is hard and ridged (the *hard palate*), the ridges helping to retain food in the mouth while chewing, while at the back of the mouth the roof is soft (the *soft palate*). Notice also (*a*) the muscular *tongue*, attached at its root to the floor of the mouth and free and movable in front, (*b*) the *epiglottis*, a stiff flap lying just behind the tongue and covering the *glottis* at the entrance to the wind-pipe, (*c*) the whiskers and eyebrows (sense-organs of touch), (*d*) the *external ears*, (*e*) the *trunk*, consisting of the chest (or *thorax*), strengthened by the ribs and breastbone on its ventral side, and the belly (or *abdomen*) with a muscular body-wall on its ventral side.

In both sexes, the combined *excretory and reproductive duct* opens in front of the *anus*. In the *male* animal, this opening is at the end of the *penis*, and on either side of the penis is a *sac* containing a *testis* which produces sperms. In the *female* animal, there is a slit-like opening. The ventral surface of the female animal also bears several pairs of *milk-glands* with milk-ducts opening at *teats*.

Dissection

Place the animal on its back on a dissecting-board, tying the limbs to hooks in the four corners of the board so as to stretch out the body. Wet the fur along the mid-ventral line.

(i) Pinch up the *skin* in the middle of the belly-surface and make a cut (*through the skin only*) with the scissors. Continue this cut forwards along the middle line to the neck, backwards to near the reproductive opening, and along the upper part of the limbs. With a sharp knife, separate the skin from the underlying muscular body-wall, and pin it out on each side. (While removing the skin, notice the *milk-glands* in the female and the *scrotal sacs* in the male.)

(ii) Pinch up the muscular *body-wall* in the middle of the belly and cut through it along the mid-ventral line, forwards to the gristly end of the breastbone, and backwards to near the reproductive opening, being careful not to injure any internal organs. Make transverse cuts just behind the ribs and across the hinder part of the belly-wall and pin back the body-wall on either side. Make a plan of the internal organs of the belly-cavity as they lie, before disturbing them. Notice (*a*) the large, reddish-brown *liver*, (*b*) the light-coloured *stomach*, partly hidden by the liver, (*c*) the much-coiled *small intestine*, (*d*) the wide, dark-coloured *caecum*, hiding most of the intestines, (*e*) the dark-coloured *colon*, (*f*) the *rectum*, containing round lumps of faeces, and (*g*) the *bladder*, containing urine.

(A male guinea-pig has a pair of long, translucent sperm-sacs—absent in rabbits.)

(The food-canal must be handled with great care while dissecting, especially the caecum; if it is punctured the contents will leak out and cover the dissection with digested food material.)

The food-canal

(iii) Having made a plan of the undisturbed internal organs, carefully turn the food canal over to the animal's left side and, without cutting or tearing anything, identify (*a*) the *liver*, hanging from (*b*) the *diaphragm*, (*c*) the *gall-bladder*, embedded in the liver, with (*d*) the *bile-duct* entering the small intestine where it leaves the stomach; (*e*) the *gullet* leading to (*f*) the *stomach*; (*g*) the *spleen*, a dark red body near the stomach (*N.B.* The spleen is not part of the food-canal); (*h*) the *pancreas*, spread out in the first loop of the small intestine and (*i*) the *pancreatic duct*. Notice that the intestines are enclosed and supported by a delicate, transparent membrane (the *mesentery*) in which run blood-vessels, lymph-vessels, and nerves, supplying all parts of the intestines. Identify the *portal vein* where it enters the liver, and ligature it in two places about half an inch apart, i.e. tie a loop of thread lightly round the vein so as to prevent loss of blood when it is cut.

(iv) Carefully remove the food-canal as follows: (*a*) Cut across the ligatured portal vein *between the ligatures*, (*b*) ligature the gullet just above the stomach and cut through *above* the ligature, (*c*) ligature the hinder end of the large intestine and cut through *below* the ligature. Now start at the hinder end and free the food-canal, cutting carefully through the supporting mesentery near the intestine and being careful not to cut the caecum or damage any large blood-vessels. (If a vessel is cut by accident, ligature it immediately to stop bleeding.) Do not damage the membrane filling the first loop of the small intestine or you may not be able to examine the *pancreas* and the *pancreatic duct*. Spread out the food-canal on a board and make a drawing, labelling the *gullet*, *stomach*, *bile-duct*, *pancreas*, *pancreatic* *duct*, *small intestine*, *caecum*, *colon*, and *rectum*. (If the animal is to be kept until a later lesson, remove the skin as far as possible at this stage.)

Other organs in the body-cavity

(v) After removing the food-canal, carefully ligature the *posterior main vein* where it branches to the liver, and remove the liver. Then examine the *diaphragm*, which separates the chest-cavity from the rest of the body-cavity, consisting of a fibrous central portion with muscles round its margin. Identify the *main artery* lying dorsal to the *posterior main vein* and notice how these main blood-vessels give off branches to the various organs and to the hind limbs. Identify the blood-vessels shown in Fig. 11. Notice the two *kidneys* with their *arteries* and *veins*, the *adrenal glands*, and the two *kidney-ducts* (or ureters), thin, white tubes leading from the kidneys to the bladder.

The reproductive organs

(vi) Examine the *male reproductive system*. Pull out the left *testis* from its sac and notice its oval shape with a mass of coiled tubes at one end which later join up to form a single *sperm-duct*. This tube loops over the *kidney-duct* and joins the sperm-duct from the right testis, opening into the neck of the *bladder* and forming a common duct which runs through the *penis*, opening to the exterior at the combined excretory and reproductive opening. Find the line where the bones of the hip-girdle meet on the ventral side, and cut through the bone at this point with a knife or a strong pair of scissors. Separate the two halves of the hip-girdle, and dissect out the reproductive organs. Draw the male reproductive and excretory organs and label the parts.

In the *female* animal, notice the two small, oval *ovaries* near the kidneys, and the two *oviducts*. Fertilization takes place in the upper part of an oviduct when a sperm fuses with a descending egg-cell. Each oviduct consists of a narrow, wavy duct leading to a wider, thick-walled *womb* (or *uterus*), where the embryo develops. The right and left uteri join to form the *vagina*, which enters the *vestibule* together with the *urethra* (the duct through which urine is discharged from the bladder). Draw the female reproductive and excretory organs and label the parts.

Organs of the chest-cavity and the neck

Notice that the exposed surface of the diaphragm is concave. Then make small cuts between the lower ribs on either side of the breastbone and notice how the diaphragm flattens out as the air enters the chest-cavity between the ribs and the lungs. Cut carefully through the ribs (except the first) on either side of the breastbone. Then cut across the breastbone and remove it. Through the opening, identify and sketch the position of (*a*) the *heart*, enclosed in a thin double-walled *heart-sac*, (*b*) the right and left *lungs* in their *pleural cavities*. Notice, too, the *muscles* between the ribs. Now cut through the ribs on either side, as near the backbone as possible, cutting *carefully* through the first rib on either side. Remove the heart-sac *very carefully*, so as to expose the main blood-vessels entering and leaving the heart. Now cut through the body-wall of the neck along the mid-ventral line and expose the underlying structures.

Identify (*a*) the thin-walled right and left *auricles*, (*b*) the thick-walled right and left *ventricles*, (*c*) the *pulmonary artery leading from the right ventricle to the lungs*, (*d*) the thick-walled *main artery* (or *aorta*) arising from the left ventricle, bending over to the left behind the heart and passing through the diaphragm into the belly-cavity as the *dorsal artery*. Note the branches given off by the main artery: (*e*) the right and left *arteries to the fore limbs*, and (*f*) the right and left *arteries to the head*. Identify the thin-walled right and left *anterior main veins* (or *superior vena cavae*) receiving blood from (*g*) the right and left *veins from the head* and (*h*) the right and left *veins from the fore-limbs*. Identify, also, the thin-walled *posterior main vein* (or *inferior vena cava*) returning blood to the right auricle from all parts of the body behind the diaphragm, and also the *pulmonary veins returning blood from the lungs to the left auricle*. Draw diagrams of (i) the arteries, and (ii) the veins, labelling the blood-vessels.

Notice the ringed *windpipe* ventral to the *gullet*, with the *voice-box* at its anterior end.

The upper end of the wind-pipe opens into the mouth by the *glottis*, protected by a stiffened flap, the *epiglottis*. Cut across the wind-pipe and tie into it a blowpipe (or the flanged end of a glass tube). Blow into the tube and watch the lungs expand.

Remove the skin from one side of the head and notice the *salivary glands*. There are four pairs of these in the rabbit and guinea-pig, two pairs behind or between the angles of the jaws, one pair under the tongue and one pair below the eye-sockets.

Notice what a large *nerve* looks like, e.g. the one supplying the fore-limb and running near the blood-vessel to the fore-limb.

Examine the large *muscle* of one of the limbs and notice how it is attached to the bones by *tendons* at either end.

Carefully remove the bones forming the dorsal surface of the skull so as to expose the *brain*. Identify the *big brain* consisting of two halves, and also the *little brain*.

Examine a prepared skeleton.

PRACTICAL WORK ON FOOD AND DIGESTION

Experiments with sugars

The chemical reactions of all the simple sugars (e.g. glucose, fructose, galactose) are very similar and may be illustrated with a 1 per cent. solution of glucose. They are all '*reducing sugars*' and will reduce copper salts to red cuprous oxide, and silver salts to metallic silver. Copper sulphate is most commonly used, in alkaline solutions.

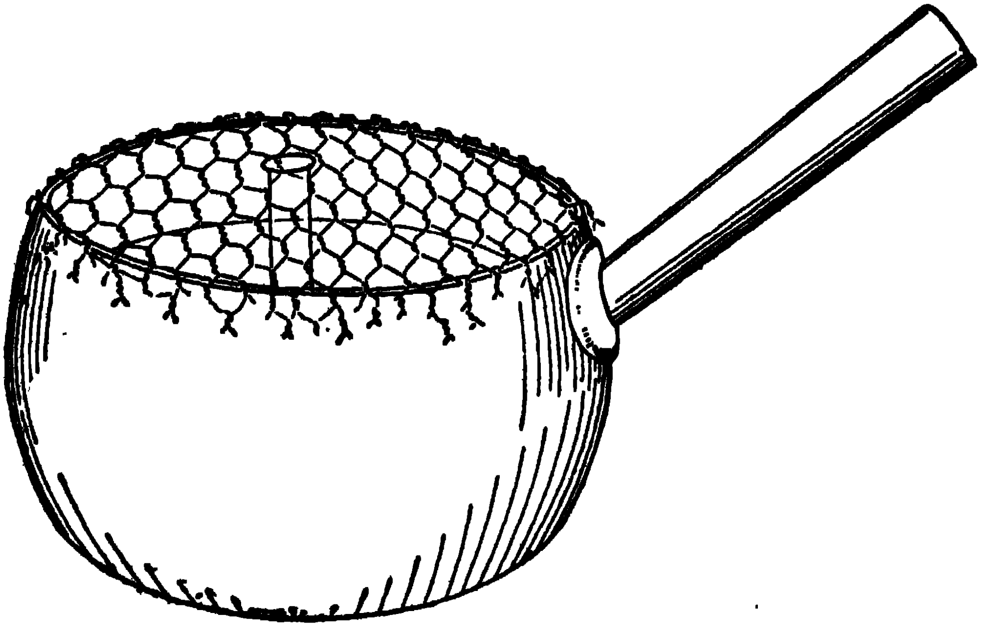


FIG. 98.—Improvised water-bath for test-tubes

Fehling's Test.—Take 2–3 c.c. of the test-solution (i.e. 1 in. in a ⅝-in. test-tube) and add an equal volume of diluted (1/5) Fehling's solution (an alkaline solution of copper sulphate containing also Rochelle salt—sodium hydrogen tartrate). Place in a boiling water-bath (see Fig. 98). A red precipitate of cuprous oxide shows the presence of a reducing sugar.

There are two kinds of complex sugars, (*a*) those that reduce copper solutions, e.g. maltose and lactose, and (*b*) those that do not reduce copper solutions, e.g. sucrose. The reducing power of the simple sugars glucose and fructose, however, is greater than that of maltose and lactose.

Repeat Fehling's test with maltose, lactose, and sucrose, and compare their reducing power with that of glucose as follows: Take five test-tubes, A, B, C, D, and E, each containing 2–3 c.c. of diluted (1/5) Fehling's solution. To A add 1 c.c. of 1 per cent. glucose solution, to B add 1 c.c. of 1 per cent. fructose solution, to C add 1 c.c. of 1 per cent. maltose solution, to D add 1 c.c. of 1 per cent. lactose solution, and to E add 1 c.c. of 1 per cent. sucrose solution. Place all five test-tubes in a boiling water-bath and notice when a precipitate of cuprous oxide appears in each tube: first in A (glucose) and B (fructose) and a little later in C (maltose) and D (lactose). Notice that *no precipitate forms in E* (sucrose). *Sucrose has no reducing action*, and the reducing power of glucose and fructose is greater than that of maltose and lactose.

To convert complex sugars into simple sugars: Take 2–3 c.c. of (*a*) 1 per cent. sucrose solution, (*b*) 1 per cent. maltose solution, and (*c*) 1 per cent. lactose solution, and add to each tube 1 c.c. of dilute hydrochloric acid. Boil for 2 min. Take four clean test-tubes A, B, C, and D, and put 2–3 c.c. of diluted (1/5) Fehling's solution in each. To A add 2 c.c. of the boiled sucrose solution; to B add 2 c.c. of the boiled maltose solution; to C add 2 c.c. of the boiled lactose solution; to D add 2 c.c. of 1 per cent. glucose solution, unboiled. Place all four tubes in the boiling water-bath and notice the rapid reduction to red cuprous oxide in every case, showing that the complex sugars sucrose, maltose, and lactose have been split up (hydrolized) into simple sugars with greater reducing power. The enzymes sucrase, maltase, and lactase produce the same hydrolysis in the small intestine.

Experiments with complex carbohydrates

Starch. Prepare a 1 per cent. starch solution as follows: Boil 75 c.c. of water in a beaker. Weigh out 1 gm. of starch and shake up with about 10 c.c. of cold water in a test-tube. Pour this suspension of starch into the boiling water, stirring well all the time. Wash out the test-tube with another 10 c.c. of cold water and transfer the washings to the beaker. Boil for one minute, cool, and then make up to 100 c.c. Use your solution for the following experiments.

(i) Take about 1 c.c. of 1 per cent. starch solution in a test-tube and add one drop of iodine solution.[1] Notice the deep blue-black colour. Fill up the tube with water and notice that the colour is still deep blue.

---

[1] A suitable iodine solution can be prepared by grinding together in a mortar 1 gm. of iodine with 5 gm. of potassium iodide in 1 c.c. of water; then dilute to 100 c.c.

(ii) Take about 1 c.c. of 1 per cent. starch solution and one drop of iodine solution, add about 5 c.c. of water and then boil. Notice that the blue colour disappears on heating. Cool under the water-tap. Notice that the blue colour returns on cooling. (*N.B.* Remember that the iodine test does not work in hot solutions.)

(iii) Take 1 c.c. of 1 per cent. starch solution and make it alkaline to litmus with sodium carbonate solution. Add a drop of iodine solution. There is no blue colour. Repeat this with 1 c.c. of 1 per cent. starch solution that has been acidified with dilute hydrochloric acid; iodine gives the usual blue colour. (*N.B.* Remember that the iodine test does not work in alkaline solutions, but only in neutral or acid solutions.)

(iv) Take a small quantity of dry rice-starch in a test-tube and shake vigorously with about 5 c.c. of cold water. Filter half the mixture. Add a drop of iodine solution to the filtrate and notice that no blue colour develops, showing that starch is insoluble in cold water. Boil the remainder of the starch suspension and then filter. Add one drop of iodine solution to the filtrate after cooling. Notice that a blue colour is produced at once, showing that starch is soluble in hot water.

Dextrin. Dextrin can be prepared by baking dry starch in a domestic oven until it just begins to turn brown. Take 2–3 c.c. of a 1 per cent. dextrin solution and add one drop of iodine solution. Notice the reddish-brown colour. (Compare this with the colour produced by adding one drop of iodine to 2–3 c.c. of water.) Heat the mixture of dextrin and iodine—the reddish-brown colour disappears. Cool under the tap and notice that the colour returns.

To convert starch into simpler carbohydrates. (i) First show that starch has no reducing action. Take 2–3 c.c. of 1 per cent. starch solution and add an equal volume of diluted (1/5) Fehling's solution. Place in the boiling water-bath. No precipitate of cuprous oxide is formed, showing that *starch has no reducing action* on Fehling's solution.

(ii) Take about 10 c.c. of 1 per cent. starch solution in a test-tube and add 1 c.c. of concentrated hydrochloric acid. Place in a boiling water-bath, noting the time. On a white tile (or on a small piece of glass laid over white paper) put 12 separate drops of iodine solution, and at the end of every minute, quickly stir the acidified starch solution with a *clean* glass rod and then remove a drop of solution on the rod and test it with one of the drops of iodine on the tile. (*N.B.* Be careful to wash the glass rod between tests.) Notice the gradual change of colour from blue (starch) to purple and then reddish-brown (dextrin); finally no colour is produced.

Pour 2–3 c.c. of the remaining solution into a test-tube and neutralize the acid with about 1 c.c. of sodium hydroxide solution (2N). Then add an equal volume of diluted (1/5) Fehling's solution and heat in a boiling water-bath. A red precipitate of cuprous oxide shows that a reducing *sugar* (glucose in this case) has been formed by acid hydrolysis of the starch. (*N.B.* Compare this splitting-up of starch by acid with that brought about by the enzyme *ptyalin* present in saliva; see p. 253.)

Tests for fats and oils

When a drop of vegetable or animal oil is placed on a piece of filter-paper (or any thin *unglazed* paper), a permanent *grease-spot* is formed. This grease-spot, unlike the spot produced by water or any liquid that evaporates, does not disappear on standing and it cannot be washed away with water. This grease-spot provides a useful test for oils and fats in fatty foods.

(i) Place one drop of coconut oil on a strip of filter-paper and notice that a permanent grease-spot is produced. (Keep this strip of paper for Expt. v.)

(ii) Place single drops of (*a*) water, (*b*) alcohol, (*c*) petrol on strips of filter-paper. Notice that although a spot is first formed in each case, the water, alcohol, and petrol soon evaporate and leave no trace behind on the paper.

(iii) If the substance under test contains little fat, we can make use of the fact that oils and fats are soluble in petrol. Take about 1 gm. of crushed soya-bean (or crushed ground-nut) in a *dry* test-tube and add about 5 c.c. of petrol (*away from flames*). Close the mouth of the tube with the thumb and shake vigorously for at least one minute. Then allow the solid material to settle to the bottom. With a narrow glass tube, remove a little petrol and allow it to fall—one drop at a time—on a strip of filter-paper, allowing each drop to evaporate before adding the next drop. Notice that a permanent grease-spot is left after the petrol has evaporated. (Keep this paper for Expt. v.)

(iv) If the food substance contains much fat, it will form a grease-spot if it is placed on a filter-paper and gently warmed. Try this with some oil-yielding seeds.

Colour test for fats.—The aniline dye Sudan III stains oils and fats orange-red. Put 1 gm. of Sudan III in a stoppered bottle with 125 c.c. of 70 per cent. alcohol. Shake until saturated and then filter. Put about 1 c.c. of coconut oil in a test-tube and add 2–3 c.c. of the Sudan III solution. Close the mouth of the tube with your thumb and shake vigorously for a minute. Then allow to stand and notice that the oil has taken up most of the dye. Half-fill the test-tube with water and shake again. On standing, the oil gradually rises to the top and is seen to be strongly coloured. Filter, and notice that the filtrate (the watery portion) is nearly colourless, showing that the oil has taken up most of the Sudan III. Place about 1 gm. of starch on a folded filter-paper in a funnel, and pour on to it 2–3 c.c. of Sudan III solution. After the solution has drained through, wash the starch on the filter-paper several times with a little water. Notice that the starch does not retain the dye (since it contains no fat).

(v) Take the strips of filter-paper from Expts. (i), (ii) and (iii); place them in a test-tube and add 2–3 c.c. of Sudan III solution. Shake and then allow to stand for several minutes. Then remove the strips and wash them with water, under the tap. Notice that the grease-spots are now stained a bright orange-red. This staining test enables us to test for fat in substances which do not give the grease-spot test readily.

Tests for proteins

Nearly all the tests for proteins depend upon reactions given by the constituent *amino-acids*, hence *all* proteins do not give *all* the various colour reactions; so that it is necessary to carry out several tests before the presence of protein is verified. Try the following tests on a solution of egg-white.

Protein–copper test.—This useful test is given by all *proteins* (in which the individual amino-acids are linked together) but *not by the individual amino-acids*. Take 2–3 c.c. of the test-solution in a test-tube and add an equal volume of sodium hydroxide solution (8 per cent.). Then add *two drops* of 1 per cent. copper sulphate solution, and shake gently to mix. Proteins give a *violet* colour at once, without heating. In doubtful cases, a control tube should be used, with 2–3 c.c. of water, an equal volume of sodium hydroxide solution, and two drops of 1 per cent. copper sulphate solution, comparing the colour of this control mixture with that given by the test-solution.

Nitric acid reaction (Teacher-demonstration).—Take 2–3 c.c. of the test-solution and add about 1 c.c. of concentrated nitric acid (CARE!). If certain amino-acids are present, a white precipitate is formed which turns *yellow* and partly dissolves on warming. *Cool* under the tap and then add excess of ammonia solution (CARE!). The yellow colour turns to orange. (You should now be able to explain the fact that nitric acid, when accidentally spilt on the skin, produces a yellow stain.)

EXPERIMENTS ILLUSTRATING DIGESTION IN THE MOUTH

(i) Place small pieces of red and blue litmus paper (or neutral, purple litmus paper) on the tip of the tongue. Notice that saliva is very slightly alkaline.

(ii) Prepare a solution of saliva as follows: Warm 50 c.c. of water in a beaker to about 37° C. and then wash out the mouth thoroughly with about 20 c.c. of the warm water. Then take another 20 c.c. of warm water in the mouth and keep it moving with the tongue for at least one minute. Collect this saliva solution in a clean beaker and filter it. Place test-tubes of saliva solution and 1 per cent. starch solution (separately) in a water-bath at about 37° C. to warm up to a suitable temperature for your experiments. On a white tile (or a glass plate over a piece of white paper) place drops of iodine solution (N/20) at regular intervals.

(iii) Put about 3 c.c. (1-in. in a ⅝-in. test-tube) of the warm 1 per cent. starch solution in a test-tube and add an equal volume of the warm saliva solution. Note the time. Shake up and place in the 37° C. water-bath.

After 30 seconds, remove a drop of the mixture with a glass rod and add it to one of the drops of iodine solution on the white tile. A blue colour shows the presence of starch, a purple or reddish colour shows the presence of dextrin, while a negative result shows that the starch is completely changed. Remove drops of the mixture every 30 seconds until there is no colour change with iodine. If this point is reached in less than 2 minutes, dilute some of your saliva solution with an equal volume of water and repeat the experiment.

(iv) When you have reached the colourless point with iodine, add an equal volume of diluted Fehling's solution (1/5) and heat in a boiling water-bath. A red precipitate shows the presence of a reducing sugar. This shows that the enzyme *ptyalin* in saliva only begins the digestion of starch, converting it to maltose, which is split up into glucose in the small intestine.

(v) Boil the remainder of the raw starch suspension from Experiment (iii) and cool under the tap. Take 2–3 c.c. of this suspension, add an equal volume of saliva solution and test at intervals with iodine. Notice that saliva digests cooked starch.

EXPERIMENTS ILLUSTRATING DIGESTION IN THE STOMACH

(i) *To show the digestion of protein by pepsin.* Put 4 c.c. of 1 per cent. pepsin solution in a test-tube and add 1 c.c. of 1 per cent. hydrochloric acid.

(1 c.c. of 1 per cent. hydrochloric acid has now been diluted to 5 c.c., so that the mixture contains 0·2 per cent. of hydrochloric acid, i.e. the same percentage as in human gastric juice.) Add a *small* piece of washed white fish-muscle and place in the 37° C. water-bath. (If a *small* piece of fish is used it will be completely dissolved and there can be no doubt about the action of the enzyme on the protein. If a large piece of fish is used it will not *all* dissolve, and it will be difficult to be sure from direct inspection whether *any* has dissolved.) Shake occasionally (to imitate the movements of the stomach) and notice that the protein gradually dissolves, i.e. it is *digested* by the pepsin. Filter the final solution and divide into two. To one half add 2 c.c. of 40 per cent. sodium hydroxide solution containing 2 drops of 1 per cent. copper sulphate solution. The characteristic purple Biuret reaction shows the presence of dissolved proteins. To the other half, add about 1 c.c. of 1 per cent. *bile-salt* (or ox-gall) solution. A white precipitate of partly-digested protein is formed. (Bile-salts precipitate *proteases* in the small intestine, thus giving the pancreatic juice a better chance to complete the digestion of the proteins in the food.)

(ii) *To show the action of rennin on milk*. Take about 5 c.c. of fresh cow's milk in a test-tube and add about 1 c.c. of rennin solution (e.g. 'essence of rennet'). Shake, and keep the tube in the 37° C. water-bath for 5 minutes. Notice that a *clot* is formed, and that the tube can be turned upside-down without any milk flowing out. The clot consists of the *casein* of the milk together with the *milk-fat*, which is carried down by the casein. Put back the tube in the 37° C. water-bath for an hour and notice how the clot gradually contracts, squeezing out a clear liquid, the '*whey*'. (This is the first stage in the process by which milk is made into cheese.) The same clotting takes place in the stomach when milk is drunk. If the milk is swallowed quickly, it forms one large, tough, clotted mass which is only digested very slowly. Hence it is better to drink milk slowly, sipping a little at a time (or, better still, through a clean drinking straw) so that loose, easily digested curds are formed in the stomach.

EXPERIMENTS WITH BILE

To show how bile lowers the surface tension of water. The following experiments may be done with diluted ox-bile (1 volume of bile to 9 volumes of water), or with a 1 per cent. solution of bile-salts.

(*a*) Take two small glass beakers. In one put 10 c.c. of distilled water and in the other put 10 c.c. of bile solution. Shake a little 'flowers of sulphur' on the liquid surface in each beaker and then rock the vessels gently. The fine particles of sulphur continue to float on the surface of the pure water owing to the high surface tension, but the sulphur sinks in the bile solution because the bile-salts lower the surface tension of the water.

(*b*) Put two similar folded filter-papers in two filter-funnels. Wet one with pure water and the other with bile solution. Then pour about 1 c.c. of vegetable oil, e.g. coconut oil, on to each filter and allow to stand for some hours. Notice that the oil will not pass through the filter-paper moistened with pure water, owing to the high surface tension of the oil-water surface. The oil gradually passes through the filter-paper wetted with bile solution, however, showing that the bile-salts lower the surface tension. This fact is of great importance in breaking up oils into very tiny drops so as to form an *emulsion*, and this is the main action of bile in the digestion and absorption of fats.

EXPERIMENTS WITH SOAP

Place in a small bottle a few grams of soap powder, soap flakes, or soap shavings; then half-fill the bottle with warm water, shake vigorously to dissolve the soap and notice the characteristic *lather*—a mass of air-bubbles with each bubble surrounded by a film of soap.

(*a*) Take three test-tubes, A, B, and C. Put 10 drops of coconut oil in each tube. To A add about 10 c.c. of water; to B add 10 c.c. of water and a few drops of caustic soda (sodium hydroxide) solution; to C add 5 c.c. of water and 5 c.c. of your soap solution. Shake all three tubes vigorously and then allow them to stand in the test-tube rack. In each case, vigorous shaking breaks up the oil into very fine drops, which are suspended in the liquid to form an *emulsion*. On standing, however, the oil-drops in A soon run together and rise to the surface to form a separate layer, i.e. the emulsion is unstable. In B, the emulsion is permanent, because the alkali combines with the oil to form a little soap, which forms a protective film round each tiny oil-drop. In C, the emulsion is also stable, for the same reason.

In the same way, when greasy or oily articles are washed with soap, the soap solution '*emulsifies*' the grease, and this emulsion can easily be washed away with water.

(*b*) (i) Put a little lamp-black (finely-divided carbon) in a test-tube and add about 10 c.c. of water. Shake vigorously. Filter half the black suspension and allow the remainder to stand. The filtrate is colourless, all the solid particles being retained on the filter. On standing, the solid particles gradually settle out from the suspension.

(ii) Put about the same quantity of lamp-black in another test-tube and add 5 c.c. of water and 5 c.c. of your soap solution. Shake vigorously. Filter the mixture, as before, and notice that the filtrate is black, each separate particle of lamp-black having been surrounded by a film of soap and thus enabled to slip through the filter. Allow the remainder of the mixture to stand—the lamp-black remains suspended in the soap solution. This experiment explains how soap removes dirt, each particle of dirt being surrounded by a film of soap so that it is readily washed away with water.

EXPERIMENTS WITH EMULSIONS

Take four test-tubes, A, B, C, and D. Put 10 drops of vegetable oil, e.g. coconut oil, in each tube. To A add 10 c.c. of distilled water. To B add 5 c.c. of distilled water and 5 c.c. of sodium carbonate solution (1 per cent.), giving about the same amount of alkali as in human pancreatic juice. To C add 10 c.c. of 1 per cent. bile-salt solution. To D add 5 c.c. of 1 per cent. sodium carbonate solution and 5 c.c. of 1 per cent. bile-salt solution. Shake all the tubes vigorously and allow them to stand in the test-tube rack. In each case, shaking breaks up the oil into very fine drops which are suspended in the liquid to form an *emulsion*. On standing, however, the oil-drops in A soon run together and rise to the surface to form a separate layer, i.e. the emulsion is only *temporary*. In B the emulsion is *permanent*, because the alkali forms a trace of soap which produces a protective film round the oil-drops.

The pancreatic juice is alkaline, and thus helps to break up oils and fats into small droplets. In C, a permanent emulsion is formed because the bile-salts lower the surface-tension between the oil and the water. In D, a very stable emulsion is formed by the combined action of the sodium carbonate and the bile-salts (both of which are present in the small intestine).

EXPERIMENTS ON DIFFUSION

One-third fill a 'sausage-skin' parchment-paper or Cellophane sac with 1 per cent. starch solution and then fill up the remaining two-thirds with 5 per cent. glucose solution. Stand the sac in a narrow jar or tall beaker of water, being very careful not to spill any of its contents into the beaker (Fig. 99). After 20 minutes, pour a few c.c. of water from the beaker into a test-tube and add a drop of iodine solution. No blue colour develops, showing that no starch (a *colloid*) has *dialysed* out through the membrane. Pour out another 2–3 c.c. of water from the beaker and test for glucose. with Fehling's solution. A red precipitate of cuprous oxide shows that some glucose (a *crystalloid*) has dialysed out through the membrane. Add a few drops of iodine solution to the remainder of the water in the beaker and set aside for half an hour. A blue colour develops *inside* the membrane, showing that iodine has dialysed through the membrane. No blue colour develops in the surrounding water, showing that no colloidal starch has dialysed outwards through the membrane.

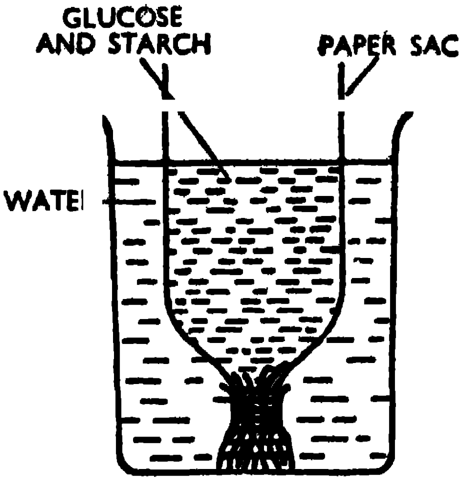


FIG. 99.—Dialysis

Digestion, therefore, prepares the food for absorption by (*i*) *converting insoluble materials into soluble substances* (e.g. starch to sugar), (*ii*) *converting the large molecules of colloids into smaller molecules of diffusible crystalloids* (e.g. proteins to amino-acids), (*iii*) *converting soluble substances into substances acceptable to the tissues* (e.g. maltose to glucose).

EXPERIMENTS ON TASTE AND SMELL

In the following experiments one student acts as the 'patient' while his partner carries out the various tests, and *vice versa*

(i) The 'patient' first washes out his mouth with water at about 37° C. and then dries his tongue with a handkerchief. He then closes his eyes and holds out his tongue while his partner applies the following solutions with a glass rod or a small, pointed brush: (*a*) *sweet* (5 per cent. sucrose), (*b*) *bitter* (1 per cent. quinine hydrochloride), (*c*) *sour* (2 per cent. citric acid), (*d*) *salty* (5 per cent. sodium chloride). Test the tip, sides, top, and back of the tongue with each solution, washing out the mouth and drying the tongue between tests. Notice the time between the *stimulus of touch* and the *sensation of taste*. Draw an outline plan of the tongue and mark on it the spots which are most sensitive to each of the four fundamental tastes.

(ii) Repeat the experiments, (*a*) immediately after washing out the mouth with water as hot as can be borne, (*b*) immediately after washing out the mouth with ice-cold water. Notice how extremes of temperature reduce the sensitivity of the nerves of taste.

(iii) Test the sensitivity of your organ of taste by describing solutions A, B, C, D, and E as *sweet*, *sour*, *bitter*, *salty*, or *tasteless*. (The solutions are very dilute and may be swallowed without fear.) (12 gm. sucrose per litre; 4 gm. sodium chloride per litre; 2 gm. sulphuric acid per litre; 0·001 gm. quinine hydrochloride per litre; distilled water.)

(iv) The blindfolded 'patient' pinches his nose (so that he cannot smell) while he bites small pieces of the following substances placed in his mouth by his partner and tries to recognize them by their *taste*: raw potato and raw onion; cooked potato and cooked onion; a clove. Notice that taste alone, without smell, is not of much use in identifying 'flavours', which are usually combinations of tastes and smells.

(v) Test the sensitivity of your organ of smell by saying which of these two large bottles of air—X and Y—contains camphor. (0·005 gm. camphor per litre of air, or less if the room-temperature is high.)

EXPERIMENTS ON THE SENSE-ORGANS OF THE SKIN

(i) *Pain-spots.*—The 'patient' is blindfolded and his 'partner' explores the 'patient's' fore-arm for *pain-spots*, using a sharp needle and pressing down firmly but without piercing the skin. (*N.B.* The 'partner' will later become the 'patient'! If a gramophone needle is used, fixed at right-angles to the end of a match-stick by a small piece of *soft* wax, there is no danger of piercing the skin since the wax yields when too much pressure is applied.) Notice that there are many spots where the 'patient' feels the sensation of touch or pressure without actual pain.

(ii) *Touch-spots.*—The touch-spots detect *light* pressure. (*a*) Explore various parts of the blindfolded 'patient's' body with a small pointed brush or a twisted piece of cotton-wool attached to the end of a match by a bit of soft wax. Notice that the 'patient' does not detect the light pressure of the brush or cotton-wool *until it is moved so as to bend the hairs growing from the skin.* These hairs, therefore, serve as sense-organs of touch. (*b*) Mount a 2-in. bristle (from an old brush) at right-angles to the end of a match-stick with soft wax, and explore various parts of the blindfolded 'patient's' skin, marking with a small spot of ink or coloured pencil those spots which are most sensitive to touch. (*N.B.* Lower the bristle *vertically* on to the skin until it bends slightly, thus getting the same pressure each time. If the bristle is dragged sideways, however slightly, it is much more readily detected. The 'patient' says 'Yes' when he feels the bristle.) (*c*) Touch various parts of the patient's skin with strips of sand-paper of different grades of roughness, beginning with the smoothest in each test. Notice which grade is first described by the blindfolded 'patient' as '*rough*' when it touches different areas of skin. (*d*) Place small objects of wood, metal, glass, silk, wool, etc., on the blindfolded 'patient's' flat palm and ask him to identify them, first *without moving the hand* and afterwards *closing the fingers over the object*. Notice the great help given by the more delicate sense of touch of the finger-tips. The following table shows the approximate distance between neighbouring touch-spots on various parts of the human body:

Tip of Tongue . . .	1 mm.	Lips (inner surface) . . .	20 mm.
Tip of Finger . . .	2 mm.	Fore-arm	40 mm.
Lips (outer surface) . .	3 mm.	Upper Arm	70 mm.

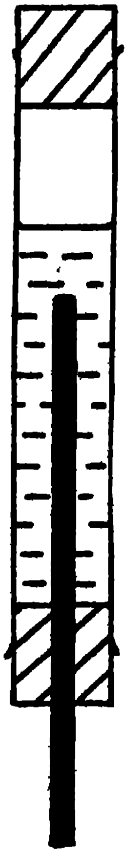


FIG. 100.—Apparatus for finding 'hot-spots' and 'cold-spots' on the skin

Notice that the tip of the tongue can distinguish between two light pressures only 1 mm. apart, hence a small hole in a tooth 'feels big' to the tip of the tongue. The tongue may 'feel' distinctly a tiny hole which the dentist can only find with difficulty!

(iii) *Hot-spots and Cold-spots.*—(*a*) Take a piece of glass tube, 6 in. by ½ in., with corks to close both ends. Through one cork put a 6-in. length of thick copper wire (S.W.G. 10–14) so that 1-in. of the wire (with a rounded end) projects outside the cork, as shown in Fig. 100. Fill the glass tube with warm water at about 50° C. and explore different areas of the blindfolded 'patient's' skin with the tip of the warm wire. The patient says 'Yes' when he feels the heat (as distinct from mere touch) and his partner marks the *hot-spots* with a small spot of ink or a coloured pencil. (*b*) Fill the glass tube with crushed ice and explore different areas of the 'patient's' skin with the tip of the cold wire, drying the wire between tests. Mark the cold-spots and notice that they are quite distinct from the hot-spots.

EXPERIMENTS ON RESPIRATION

To compare inspired air, expired air, and air from the air-sacs. **(i) Take three similar gas-jars, A, B, and C. Fill B and C with water and invert in a gas trough. Using a piece**

of rubber tube, fill B with *expired air* by breathing out normally through the tube (see Fig. 103). Fill C with air from the *air-sacs* of the lungs by holding the nose and breathing out through the tube *at the end of a forced expiration.* Invert the three jars, in turn, over a lighted candle, noting the time the candle continues to burn in each case. Repeat the experiment.

	(*a*) Fresh air.	(*b*) Expired air.	(*c*) Air-sac air
Experiment I			
Flame extinguished in	........sec.	........sec.	........sec.
Experiment II			
Flame extinguished in	........sec.	........sec.	........sec.
Experiment III			
Flame extinguished in	........sec.	........sec.	........sec.
Average	........sec.	........sec.	........sec.

What do your results suggest? ....

....

FURTHER EXPERIMENTS ON RESPIRATION

To compare inspired air, expired air, and air from the air-sacs. (ii) Take a burette fitted with a rubber tube and a spring clip; pour 50 c.c. of water into it and record the level. Then fill to the top with water, close the clip and invert in a trough of water. Open the tap and admit 50 c.c. of fresh (inspired) air, taking care that the water levels inside and outside the burette are approximately the same. Close the clip and put a well-fitting rubber cork in the open end of the burette—under water. Holding the burette the right way up, quickly remove the cork and drop in 5 pellets of sodium hydroxide; then replace the cork. Shake the burette until all the sodium hydroxide has dissolved, then invert the burette in water and remove the cork. Cool the air to its original temperature by pouring water over the outside of the burette, and then adjust the water levels as before, making sure before reading off the volume of the air that all the liquid has drained down from the narrow tube just below the clip. Record the new volume below. (Notice that there is little or no change in volume, since fresh atmospheric air contains so very little carbon dioxide—0·03 per cent.) Cork the burette again, under water, and then, holding it the right way up, quickly take out the cork and put in about 0·1 gm. of *pyrogallol.* Replace the cork and shake the burette so as to absorb all the oxygen. (The 'alkaline pyrogallol' turns brown as it absorbs the oxygen.) Then invert the burette and remove the cork under water. Notice how the water rushes in to take the place of the oxygen which has been absorbed. After cooling the gas to its original temperature, read off the new volume and record below. The gas which remains is nitrogen (mixed with a small quantity of the 'inert gases').

Repeat the experiment, first putting 50 c.c. of *expired air* into the burette by breathing out *normally* through a short rubber tube attached to the burette. (Put in more than 50 c.c. at first, cool the air down to room temperature by pouring water down the outside of the burette, then allow any excess of air to escape by opening the clip and adjusting the water level.)

Again repeat the experiment, first putting 50 c.c. of air from the *air-sacs* into the burette by holding the nose and breathing out *at the end of a forced expiration.*

	Fresh air	Expired air	Air-sac air
Original volume of air	50 c.c.	50 c.c.	50 c.c.
Burette reading at start of experiment			
Burette reading after shaking with sodium hydroxide			
Therefore, volume of carbon dioxide absorbed = ...			
Therefore, percentage of carbon dioxide = ...			
Burette reading after shaking with alkaline pyrogallol			
Therefore volume of oxygen absorbed = ...			
Therefore, percentage of oxygen =			
Therefore, percentage of nitrogen =			

Notice that the percentage of carbon dioxide in expired air is greater than that in fresh air, while the percentage of oxygen is less. The percentage of nitrogen, however, remains about the same. Notice also, that air from the air-sacs contains still more carbon dioxide and still less oxygen, though the percentage of nitrogen remains almost unchanged.

(iii) Fit up the apparatus shown in Fig. 14. Half-fill both test-tubes with clear lime-water. Apply the mouth to the 'T'-tube, hold the nose, and breathe gently in and out through the mouth. The air enters by way of A and leaves by way of B.

Notice that the lime-water in B turns chalky long before that in A, showing that expired air contains much more carbon dioxide than inspired (fresh) air.

APPENDIX C

ELEMENTARY CHEMISTRY AND PHYSICS APPLIED TO HEALTH SCIENCE

(NOTE TO TEACHERS—Health Science is an 'applied science' and can only be taught effectively if the student understands something of the 'pure sciences' (physics, chemistry, and biology) upon which it is based. Most of the necessary biology has been incorporated in the main text of this book, but some of the essential physics and chemistry is more conveniently arranged here in Appendix C, where it may be studied at appropriate times during the Health Science course.)

EXPERIMENTS ON BURNING AND BREATHING

A few simple experiments will help you to understand that the burning of fuels and your own breathing are very similar things.

(i) Bend a few inches of wire round a short piece of candle, as shown in Fig. 101, so that it will stand in a dish or deep plate containing about an inch of water. Light the candle, and when it is burning steadily, put a clean, dry glass jar mouth downwards over the burning candle. Notice that after a short time *the candle flame goes out* and then *the water rises in the jar* (see Fig. 102). Also, a dew is formed on the inside of the jar.

FIG. 101.—Candle stand

This experiment shows that the air is made up of at least two different gases, one of which (the 'active air') is used up by the burning candle while the other (the 'inactive air') is left behind unused. The modern name for 'active air' is *oxygen*, and this gas makes up one-fifth of the air (by volume). The remaining four-fifths (the 'inactive air') is mainly *nitrogen*. It is the oxygen which, by uniting with a burning fuel, sets free *heat energy*. In much the same way, it is the oxygen of the air that changes part of your food into the energy you need to move your muscles.

(ii) Collect some 'breathed-out' air as follows: Fill a glass jar with water, close the mouth of the jar with the palm of your hand, and invert it in a dish containing about two inches of water. Put one end of a rubber or glass tube under the mouth of the jar and blow through the other end until the jar is full of air from your lungs (see Fig. 103). Then remove the tube, close the mouth of the jar with your hand, and lift it out of the dish. Invert this jar of 'breathed-out' air over a lighted candle standing on a board, and count the number of seconds until the flame goes out.[1] Write down this figure in the space below. Light the candle again, after removing the jar, and then invert the same jar filled with *fresh air* over the lighted candle. Again take the time for the flame to go out. The candle burned for ..... seconds in breathed air, and for ..... seconds in fresh air.

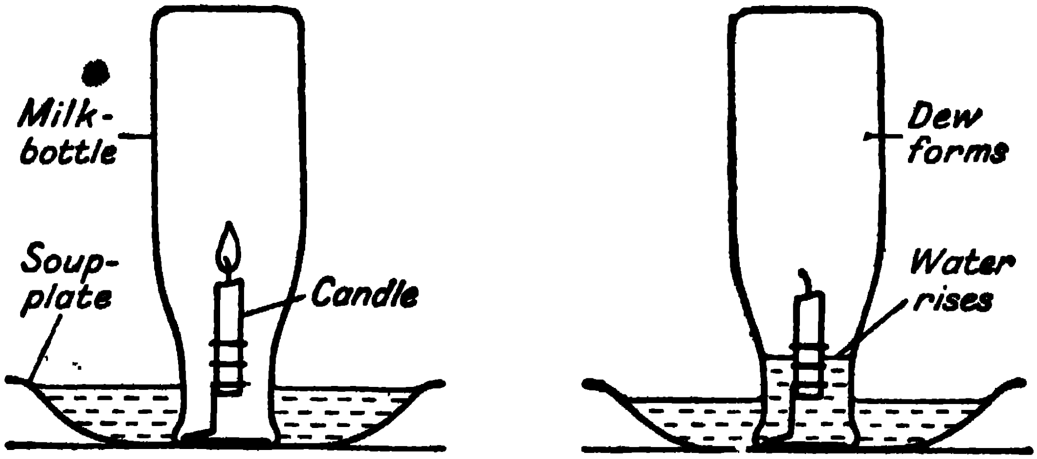


FIG. 102.—Candle burning in air

This experiment shows that breathing, like burning, uses up oxygen from the air. (The flame does not go out at once in the breathed air, showing that breathing does not use up *all* the oxygen.)

The dew that formed on the inside of the dry glass jar in Expt. (i) is *water* formed by some of the oxygen in the air uniting with part of the burning candle-wax. When you breathe hard into a clean, dry glass jar, a similar dew is formed and for a similar reason: water is one of the products formed when oxygen from the air unites with part of your food. The next experiment will show that something else is formed both during the burning of fuels and during breathing.

---

[1] There is no need to use a watch, just count, 'And one, and two, and——'

(iii) In Expt. (i) we could see that part of the air is used up. But where has it gone? It is still inside the jar, partly in the form of water (the dew on the inside of the jar) and partly in the form of a colourless gas mixed with the 'inactive air' at the end of the experiment. This new gas is called *carbon dioxide*, and we can show that it is formed during the burning of fuels and during breathing as follows: (*a*) Pour about half an inch of clear *lime-water*[1] into a jar of *breathed air*. Close the mouth of the jar with the palm of your hand and shake it vigorously. Notice that the lime-water turns chalky or cloudy. (*b*) Repeat the experiment with a jar of *fresh air*. Notice that the lime-water remains clear. These two experiments show that breathed air contains much more carbon dioxide than fresh air. (*c*) Invert a jar of fresh air over a lighted candle standing on a board as in Expt. (i), and after the flame has gone out, remove the jar and add some clear lime-water. Close the jar and shake it as before. Notice that the lime-water turns chalky, showing that carbon dioxide is formed during burning in the same way as during breathing.

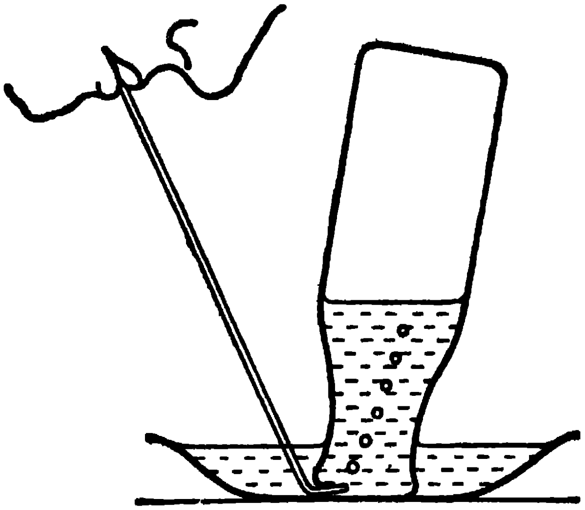


FIG. 103.—Collecting expired air

These simple experiments show that the burning of fuels and breathing are very similar changes: they both use up oxygen from the air and replace it with carbon dioxide and water vapour. When substances unite with oxygen in this way they are said to be *oxidized* and the process is called *oxidation.*

---

[1] Lime-water is made by shaking-up a little lime with a lot of water in a bottle. If the bottle is allowed to stand for a while, the clear lime-water can be poured off. The lime is made by heating limestone 'shells' or coral red hot.

COMPOSITION OF THE ATMOSPHERE

The above experiments throw some light on the composition of the atmosphere, which we can now discuss in more detail.

The atmosphere is a layer of air, at least 100 miles thick, that surrounds the Earth. The air is a mixture of gases, and we have seen that about one-fifth of its volume is 'active air' (which supports breathing and burning) and about four-fifths is 'inactive air' (which takes no active part in breathing or burning). The chemical name for 'active air' is *oxygen*, and this makes up 21 per cent. of the air (by volume). The 'inactive air' makes up 79 per cent. of the air, 78 per cent. of this being *nitrogen* while the other 1 per cent. consists of the '*rare gases*', which are even less active than nitrogen. Besides these gases, air always contains a very small quantity (0·03 per cent.) of *carbon dioxide* (see Fig. 104).

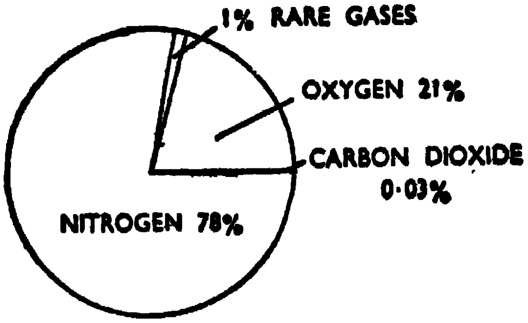


FIG. 104.—Composition of air by volume

The atmosphere also contains some *water-vapour*, but the amount varies greatly from place to place and from day to day, and it always contains tiny particles of solid matter, or *dust*, in varying amounts.

Oxygen.—Everyone knows that air is essential for life. It is the *oxygen* in the air that enables animals and plants to live in it, and without oxygen all living things would die. Oxygen is also necessary for *burning*, *rusting*, and *decay*.

Nitrogen.—The nitrogen in the air takes no active part in breathing, burning, rusting, or decay, but when it is chemically combined with other elements it is extremely important, since it forms an essential constituent of the food of animals and plants and enters into the composition of all living matter.

The rare gases.—The air contains five 'rare gases', but they are so inactive that it would make little difference to the air if they were not present at all.

Carbon dioxide.—Although the proportion of carbon dioxide in the air is so small (only 0·03 per cent. or 300 parts per million parts of fresh air) it is extremely important, since *green plants in sunlight* take in carbon dioxide from the air and use it for manufacturing substances like sugar and starch, which form the greater part of the plant's food. From our point of view, this is perhaps the most important process taking place on the Earth, for the food of all animals (including Man) is obtained from green plants, either directly or indirectly.

Water-vapour.—We have all seen that the outside of a glass filled with ice-water quickly becomes covered with drops of a clear liquid. This is because water-vapour from the air has condensed on the cold surface. The importance of water-vapour in the air is discussed on pp. 277–9.

Solid matter in the air—dust.—Ordinary air always contains some dust; particles of solid matter that are so small that they float in the air, particularly in moving air. When viewed under the microscope, dust is seen to consist of material from many different sources, e.g. unburnt carbon (soot) from fires; bits of cotton and wool from clothing; bits of animal hair and skin; rock-dust and very fine sand stirred up by the feet of animals and the wheels of vehicles, or carried by the wind from bare patches of the Earth's surface. Besides these *non-living* particles, air always contains '*living dust*'. These *living* particles are mainly *bacteria* and the spores of *moulds*. These are small enough to float about in the air until they reach a suitable place to grow.

AIR PRESSURE

We live at the bottom of a vast sea of air, at least 100 miles deep, and this great depth of air exerts a great *pressure*. We can show this by the following simple experiments:

(i) A small quantity of water is put in a boiling-tube (a large test-tube), which is fitted with a cork and a glass tube as shown in Fig. 105. The water is heated over a flame until it boils vigorously and steam escapes freely from the end of the glass tube. The boiling-tube is then removed from the flame and quickly inverted, with the end of the glass tube under water. After a moment, water rushes up the glass tube and fills the boiling-tube. The explanation of this is that when water boils it forms 1,700 times its own volume of steam, and this steam drives all the air out of the boiling-tube. Hence, after the water has been boiling for a few seconds, the boiling-tube contains nothing but steam in the space above the boiling water. When the tube cools, however, the steam changes back again into liquid water; and since 1,700 c.c. of steam condense to form only 1 c.c. of water, the pressure inside the boiling-tube is greatly reduced. The

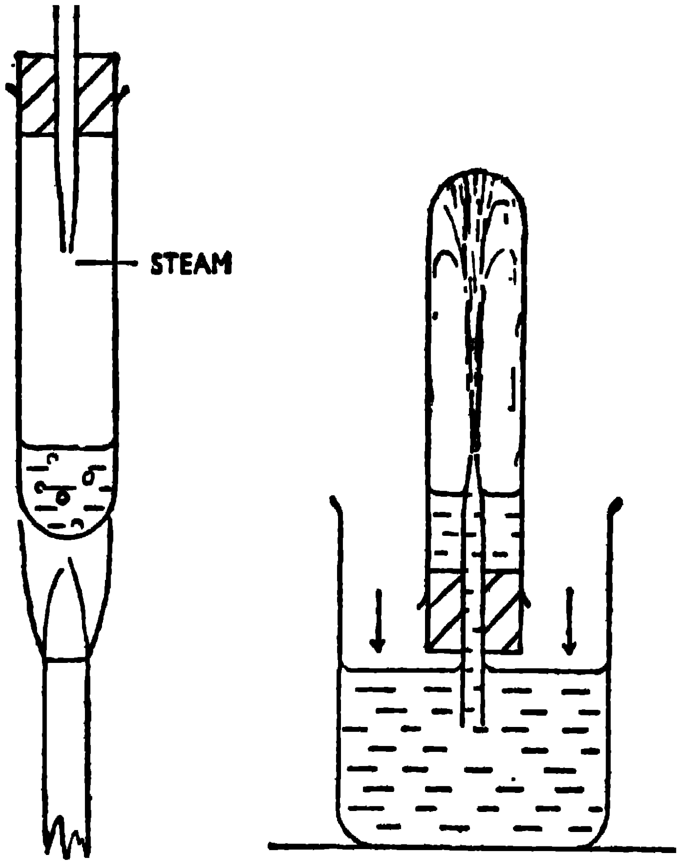


FIG. 105.—Water forced in by air pressure

pressure of the air on the surface of the water outside, therefore, pushes water into the empty space above the water inside the boiling-tube. The force with which water rushes into the boiling-tube shows clearly that the air exerts a great pressure.

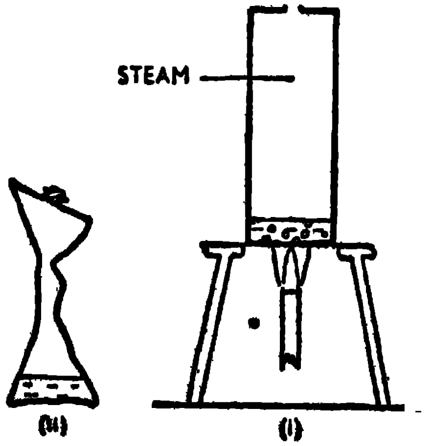


FIG. 106.—Tin crushed by air pressure

(ii) A little water is poured into a tin can and boiled so as to displace the air by steam. (See Fig. 106. A quart can with a spring cap—of the kind used for motor-oil—is very convenient for this experiment.) When steam is escaping freely, the can is removed from the flame and its mouth is corked tightly. Cold water is then poured over the can and the steam condenses, greatly reducing the pressure inside the can (since all the air was displaced by steam). The pressure of the atmosphere crushes the can. (The way in which the can collapses suggests that *the air presses equally in all directions*, and not just downwards.)

These two experiments show clearly that the air exerts a very great pressure, and it seems strange that we do not notice this in our everyday life. This is because the pressure is exerted equally in all directions and because our bodies are specially adapted to work under this pressure. The following experiment enables us to *measure* the pressure of the air in pounds per square inch.

(iii) We can get a rough value for the pressure of the atmosphere by using an ordinary bicycle-pump. The arrangement is shown in Fig. 107. The hole in the end of the pump is closed with a screw (or with a round piece of wood screwed tightly into the hole) and the cup-shaped leather washer inside the pump is reversed and well oiled (using *thick* oil). Before beginning the experiment, the piston is pushed in as far as it will go so as to displace most of the air from inside the pump. Weights are then hung from the handle of the pump. It is found that the piston does not slide down when weights of a few pounds are added, because the pressure of the atmosphere on the back of the piston and washer is too great. When just sufficient weight has been added to pull down the piston we know that this weight balances the pressure of the atmosphere. This weight, therefore, is equal to the force exerted by the air on an area equal to the cross-section of the pump-cylinder.

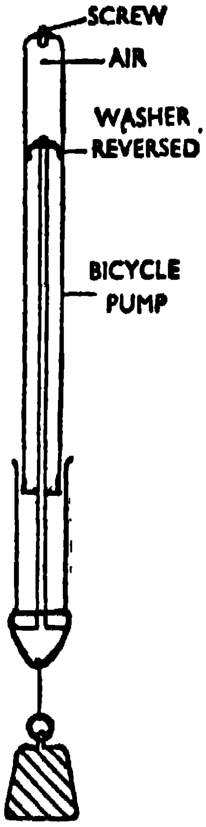


FIG. 107.—Measurement of air pressure

Weight supported = ... pounds

Inside diameter of pump-cylinder = ... inches

Therefore,

Area of cross-section of pump (πr^2) = 3·14 × (......)^2

= ...... sq. in.

Hence, ... sq. in. supports a force of ...... pounds.

Therefore, 1 sq. in. supports a force of ...... ÷ ...... pounds,

so the *pressure of the air* is ...... pounds per sq. in.

Measurement of air pressure—the barometer

Since this *air pressure* is very important in everyday life, it is necessary to have some means of measuring it accurately, and the instruments used for this purpose are called *barometers.* A simple barometer is shown in Fig. 108. A thick-walled glass tube, about 3 ft. long, is sealed up at one end. To the other end is attached another short piece of glass tube, by means of thick rubber tubing. While the tubes are held as shown in the left-hand diagram, mercury is poured in until it can just be seen above the rubber in the shorter glass tube. The apparatus is then bent into the shape of a J, as shown in the right-hand diagram, and the tubes are held in the vertical position by means of clamps. It is found that the mercury in the long glass tube falls slightly, leaving an *empty space* (i.e. a *vacuum*) between its surface and the top of the tube. There can be no doubt that the space above the mercury is a vacuum because we first filled this tube quite full of mercury and no air entered this tube when the apparatus was bent into a J. The column of mercury inside the barometer tube is balanced by the atmosphere pressing on the surface of the mercury in the open tube, hence the *vertical height between the two mercury surfaces* is a measure of the air pressure. It is found that the column of mercury supported by the air pressure is usually about 30 in. (or 760 mm.) high.

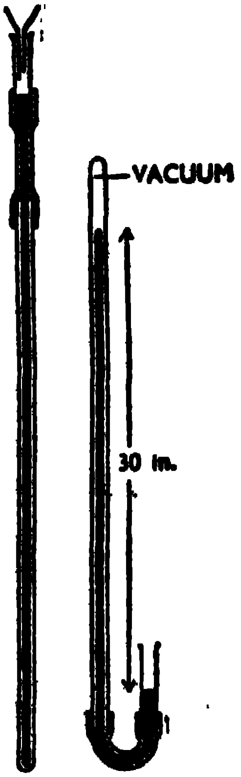


FIG. 108.—Simple barometer

If we know the weight of a cubic inch of mercury, we can easily calculate the pressure of the air in pounds per square inch. Suppose the area of cross-section of the barometer tube is *one square inch.* It will therefore contain 30 cu. in. of mercury supported by the air pressure. But 1 cu. in. of mercury weighs 7·85 ounces, therefore 30 cu. in. of mercury weigh 30 × 7·85 = 235·5 ounces = 14·7 pounds. So when the height of the barometer is 30 in. *the pressure of the air is 14·7 pounds per square inch* (i.e. almost one ton per sq. ft.).

Air pressure and the human body.—The total surface area of an average man's body is about 10 sq. ft., hence the total force pressing on his body amounts to about 10 *tons.* We do not feel uncomfortable under this great pressure because it is exerted equally in all directions and because our bodies are specially adapted to work under this high pressure; in fact, if this pressure is much reduced we soon begin to feel very uncomfortable. For example, men who fly at great heights or who climb high mountains, where the pressure of the air is low, have great difficulty in breathing and may bleed at the nose, ears, eyes and throat because the pressure of the air is less than the pressure of the blood. Near the top of Mt. Everest (29,000 ft.) a man gets only one-third as much air into his lungs at each breath as he does at sea-level. (For the first few thousand feet, a rise of 900 ft. causes the mercury column in a barometer to fall one inch.)

THE MEASUREMENT OF TEMPERATURE AND HEAT ENERGY

The word 'heat' is in common everyday use, although many people that use it may not be able to say exactly what 'heat' is; in fact, there is much confusion between two quite different ideas—*heat* and *temperature*.

When we say that a piece of iron is 'red-hot' or 'at a red heat', we mean that it is at a *high temperature*. This word 'temperature' should be used to describe the 'degree of hotness' of an object, i.e. how hot it is. If one object is hotter than another, we say that it is at a higher temperature. *Heat* is not the same thing as *temperature* or '*hotness*'. Heat is something which must be added to a cold object to make it less cold, or taken away from a hot object to make it less hot.

The measurement of temperature

Up to the end of the sixteenth century, there were no special instruments for measuring temperature, and people depended on their sense of touch to test how hot an object was. But we cannot always depend on our senses for measurements of this kind, as the following experiment shows:

Take three large basins, the first containing ice-cold water, the second containing water which is just pleasantly warm (luke-warm), and the third containing hot water (but not so hot as to burn your skin). Place your right hand in the hot water and your left hand in the cold water, and hold them there for at least one minute. Then quickly place both hands together in the other basin of luke-warm water. You will find that it does not feel the same to both hands. Your right hand (which has been in the hot water) tells you that the luke-warm water feels cold, while your left hand (which has been in the ice-cold water) tells you that the luke-warm water feels hot. It is clear, therefore, that we cannot always depend on the information we get from the sense-organs of our skin about the 'hotness' of things. To overcome this difficulty, *thermometers* are used to measure *temperature*.

Thermometers

For most everyday purposes we use *mercury thermometers*, which depend on the fact that when a liquid is heated its volume increases, i.e. it *expands*. The simplest kind of thermometer is made from a piece of thick-walled glass tubing with a very fine bore, blown out into a bulb at one end as shown in Fig. 109. The bulb and tube are filled with mercury and are then warmed to a temperature slightly higher than the highest temperature that the thermometer will ever be required to measure. The upper end of the tube is then sealed off, usually with a small 'safety bulb' at the top of the stem. After cooling, the bulb and the lower part of the stem contain mercury while the space above the mercury is completely empty, i.e. a vacuum. When such a thermometer is warmed, the mercury expands and rises up the stem, while if the instrument is cooled the mercury contracts and falls in the stem.

How thermometers are graduated

To be of practical use in measuring and comparing temperatures, thermometers must all be graduated in the same way, and the first step is to mark on each thermometer *two standard temperatures*, or *'fixed points'*.

The lower fixed point is the temperature at which pure ice melts.

The higher fixed point is the temperature of steam from water boiling in an open vessel.

The two fixed points are defined in this way because it is always easy to get pure ice and pure steam from boiling water.

Centigrade thermometers

For most scientific work, and for everyday purposes in some countries, the *Centigrade scale* of temperature is used. On this scale, the *lower fixed point* is called 0° *Centigrade* (0° C.), and the *higher fixed point* is called 100° *Centigrade* (100° C.). The interval between the two fixed points is divided into 100 equal parts called *Centigrade degrees*.

Fahrenheit thermometers

For everyday purposes in British and American countries the *Fahrenheit scale* of temperature is used. On the Fahrenheit scale, the *lower fixed point* is called 32° *Fahrenheit* (32° F.), and the *higher fixed point* is called

212° *Fahrenheit* (212° F.). The interval between the two fixed points is divided into 180 equal parts called *Fahrenheit degrees. Hence 180 Fahrenheit degrees = 100 Centigrade degrees* (see Fig. 110).

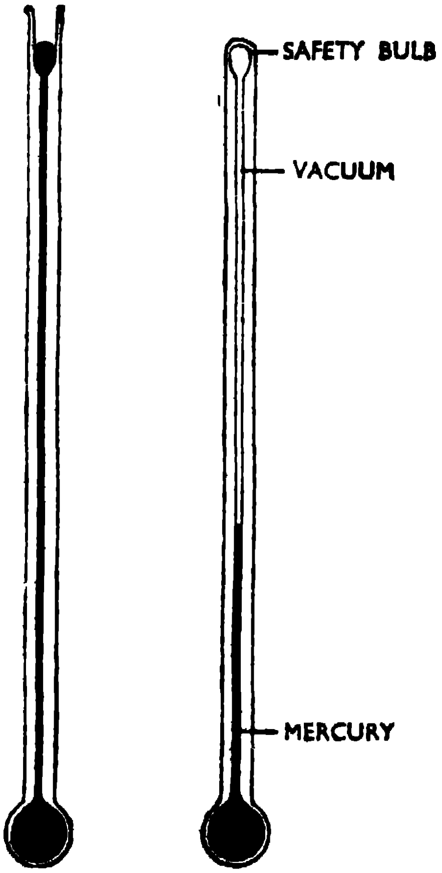


FIG. 109.—Making a thermometer

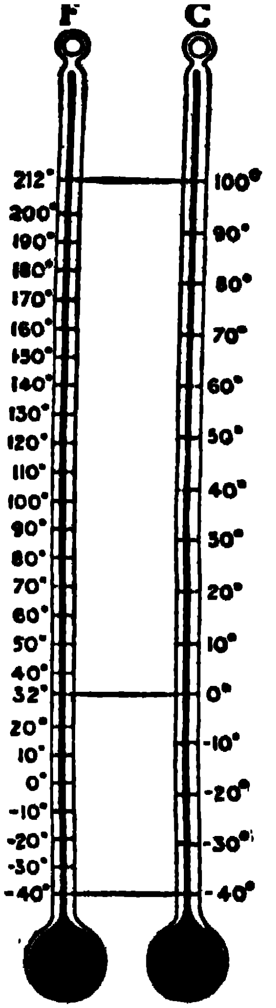


FIG. 110.—Scales of temperature

Inter-conversion of Centigrade and Fahrenheit scales of temperature

If you remember that the lower fixed point is 0° C. or 32° F., and that the higher fixed point is 100° C. or 212° F., it is easy to change Centigrade readings into Fahrenheit, and vice versa.

Example.—What is 30° C. on the Fahrenheit scale?

30° C. is 30 Centigrade degrees above the lower fixed point.

But 100 Centigrade degrees = 180 Fahrenheit degrees.

Therefore, 30° C. is $\frac{30 \times 180}{100} = 54$ Fahrenheit degrees above the lower fixed point, which is 32° F., hence 30° C. is $54 + 32 = 86$° F., *Example.*—What is 77° F. on the Centigrade scale?

77° F. is $77 - 32 = 45$ Fahrenheit degrees above the lower fixed point, i.e. $\frac{45 \times 100}{180} = 25$ Centigrade degrees above the lower fixed point, which is 0° C., hence 77° F. $25 + 0 = 25°$ C.

The clinical thermometer

The normal temperature of a healthy person's blood is 98·4° F. (= 37° C.), and by measuring any variations from this normal temperature a doctor can get useful information about a patient's health. If an ordinary thermometer were used for this purpose, the instrument would have to be read while it was still in the patient's mouth, and this would be inconvenient. So it is much better to use a special type of thermometer, graduated from 95° F. to 110° F. in fifths of a degree, designed to record the *maximum* temperature reached in the patient's mouth. In the clinical thermometer, the bore of the stem is very narrow at a point just above the bulb, as shown in Fig. 111. When the instrument is placed in the patient's mouth, the mercury expands and its expansion pushes it through this narrow bore and along the stem. When the thermometer is removed from the mouth, the mercury in the bulb cools and contracts, but the mercury in the stem cannot return through the narrow bore by its own weight and therefore stays where it was when the thermometer was in the patient's mouth. A clinical thermometer, therefore, can be taken out of the mouth and read in a good light. To re-set the instrument for a fresh observation, it is necessary to shake or swing it sharply and thus force the mercury in the stem to return through the narrow part into the bulb. The glass stem of the thermometer usually acts as a lens to magnify the very fine thread of mercury so that it is more easily seen.

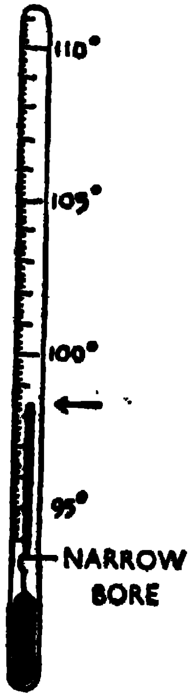


FIG. 111.—The doctor's thermometer

THE MEASUREMENT OF HEAT ENERGY

Temperature, or 'hotness', is usually measured with a *thermometer*, but a thermometer will not measure the *amount of heat* contained in the hot material. If a thermometer is placed in a test-tube full of boiling water it will show the same *temperature* as when placed in a bucketful of boiling water, although there is clearly a big difference in the *quantity of heat* present in each case.

When we are dealing with the *quantity of heat* in a substance, it is clear that the *weight* of the hot substance has to be considered as well as the temperature.

Units of heat

The *scientific unit of heat,* used in physical laboratories, is the *gram-calorie* or ('small calorie'), and this is *the amount of heat required to raise the temperature of 1 gram of water through 1° C.* Thus, when 100 gm. of water is warmed through 10° C., e.g. from 30° to 40° C., we say that 1,000 calories of heat have entered the water.

When dealing with the quantity of heat-energy used by human beings, however, this gram-calorie is inconveniently small, so a larger unit is used, the *kilo-calorie* or ('large-calorie') which is equal to 1,000 'small calories', i.e. a *kilo-calorie* is the amount of heat required to raise the temperature of 1 kilogram (1,000 grams) of water through 1° C.

Change of state and latent heat

Matter can exist in three different *physical states*: as a *solid,* as a *liquid,* or as a *gas.* By suitable heating or cooling it is possible to change most substances from one state to another. These *changes of state,* from solid to liquid and back again from liquid to solid, or from liquid to gas and back again from gas to liquid, are accompanied by important heat effects.

For example, when a vessel of crushed ice is placed in a warm room, its temperature remains constant at 0° C. as long as any ice remains unmelted. (We make use of this fact in marking the lower fixed point on a thermometer.) Although the temperature of the ice has not risen, heat from the warm air has been passing into the ice all the time it has been melting. As soon as all the ice has melted (but not before) the temperature of the water begins to rise and goes on rising until it reaches the same temperature as the air around it.

Similarly, when a vessel of water is heated over a flame, its temperature rises until it boils at 100° C. But all the water is not changed into steam immediately; and although the water continues to receive heat from the flame, the temperature remains steady at 100° C. until all the water has boiled away. (We make use of this fact in marking the higher fixed point on a thermometer.)

Thus, when ice melts and when water boils, *heat is supplied to the substance without producing any rise of temperature.* This heat, which seems to become 'hidden away' in the melting ice or in the boiling water, is called *latent heat*, and its energy has been used in forcing the molecules of the substance farther apart, since the molecules of liquid water are farther apart than those of solid water (ice), and the molecules of gaseous water (steam) are farther apart than those of liquid water.

The latent heat of a substance is the number of gram-calories required to change one gram of it from the solid state to the liquid state, or from the liquid state to the gaseous state, WITHOUT CHANGE OF TEMPERATURE.

The latent heat of water (or the latent heat of melting of ice) is 80 gram-calories per gram of water, i.e. to convert 1 gram of ice at 0° C. into 1 gram of water at the same temperature requires 80 gram-calories of heat energy. In other words, it requires as much heat to melt 1 gram of ice as it does to raise the temperature of one gram of water from 0° C. to 80° C. Conversely, since it takes 80 gram-calories of heat to melt 1 gram of ice, this amount of heat-energy will be given out when 1 gram of liquid water freezes. In an ice-box, for every gram of ice that melts, 80 gram-calories are taken from the air and food inside the ice-box. So if heat does not enter from outside, a little ice will have a large cooling effect. If we make ice melt more quickly, e.g. by adding salt, latent heat will be taken from the surroundings more rapidly and we have a *freezing mixture.*

The latent heat of steam (or the latent heat of vaporization of water) is 536 gram-calories per gram of water, i.e. to convert 1 gram of boiling water at 100° C. into 1 gram of steam at the same temperature requires 536 gram-calories of heat-energy. In other words, it requires 536 times as much heat to change 1 gram of water at 100° C. into steam at 100° C. as it does to heat 1 gram of water from 99° C. to 100° C. Conversely, when steam condenses to water, it gives out just as much heat as was required to vaporize it, so that when 1 gram of steam at 100° C. condenses to water at 100° C. it gives out 536 gram-calories of heat. One practical result of this is that steam at 100° C. contains more heat-energy than boiling water at 100° C. Hence a burn from steam is more severe than a burn from boiling water, although both may be at the same *temperature.*

When a liquid evaporates it absorbs heat-energy, either from its surroundings or from the liquid itself. This is why it may be dangerous to sit about in damp clothes, particularly in a cool breeze. The water evaporates and takes the necessary latent heat from the body, thus chilling it. In the same way, water can be kept cool in canvas bags, animal skins, or porous earthenware vessels. The latent heat required for evaporation of the thin film of water on the outside of the porous vessel is taken from the water inside, hence its temperature is lowered. (We shall see, on p. 279, that the *wet-bulb thermometer* is cooled in the same way.) Our bodies lose heat by the evaporation of sweat (which is mainly water) from the skin. When we consider that in a tropical climate a healthy man may lose *several litres* of water per day by sweating, and that each litre of water requires 536 kilo-calories for its evaporation, it is clear that very large amounts of heat-energy are removed from the body by the evaporation of sweat. Notice, however, that sweating has no cooling effect unless the sweat *evaporates* from the surface of the skin.

WATER-VAPOUR IN THE ATMOSPHERE

Owing to constant evaporation from seas, lakes, and rivers, and because of the *transpiration* of plants, the air always contains water-vapour, varying in amount from place to place, from day to day, and even from hour to hour. The presence of this water-vapour is shown by the drops of water that form on the outside of a vessel containing ice-water. The measurement of the amount of water-vapour in the air is called *hygrometry*, and the instruments by which it is measured are called *hygrometers*.

Usually, the air is not completely saturated with water-vapour, but if it is cooled sufficiently it will become saturated, and any excess of water-vapour will condense as *dew*, *cloud*, *rain*, or *mist*, according to the conditions under which cooling takes place.

Measurement of the dampness of the air

There are various ways of measuring and expressing the dampness of the air; we shall deal with them briefly in turn and then discuss their practical value in everyday life.

(i) *The actual vapour-pressure.*—If some water is put into a corked bottle containing dry air, the water begins to evaporate and its vapour sets up a '*vapour-pressure*' which can be measured, e.g. in a barometer tube (see p. 270). If there is an excess of water, evaporation continues until the air is *saturated*; it can then hold no more water-vapour and the vapour pressure reaches its maximum figure for that particular temperature. For example, at 10° C. the saturated vapour-pressure of water is 9·2 mm. of mercury, at 20° C. it is 17·5 mm., at 30° C. it is 31·8 mm., at 40° C. it is 55·3 mm. of mercury. Normally, air is unsaturated and the water-vapour is not exerting its maximum vapour-pressure. We can therefore express *humidity* (the degree of dampness of the air) as *either* the vapour-pressure itself, *or* as the *saturation deficit* (which means the difference between the actual vapour pressure of the atmosphere and the vapour-pressure of a saturated atmosphere at the same temperature). For example, suppose that at a temperature of 30° C. (= 86° F.) the *actual* vapour-pressure were 19·1 mm., then the *saturation deficit* would be (31·8 − 19·1) = 12·7 mm. of mercury. A knowledge of *saturation deficits* is useful because evaporation from wet surfaces is often proportional to it.

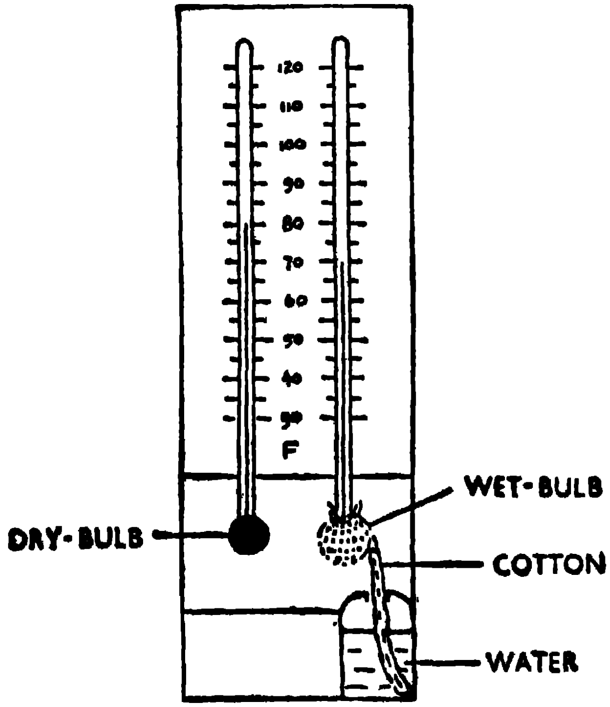


FIG. 112.—Wet- and dry-bulb thermometers

(ii) *The dew point.*—Air which is not already saturated with water-vapour will become saturated if the temperature is sufficiently lowered, and the *dew point is the temperature to which the air must be cooled before it begins to deposit water on a surface.* In other words, it is the temperature at which the water-vapour actually present in the air would completely saturate it. The dew point gives a useful indication of the amount of water-vapour present (i.e. its vapour-pressure), but unfortunately both dew point and vapour-pressure are not easy to measure accurately by direct methods. We can, however, obtain figures for dew points and vapour-pressures from prepared tables[1] if we read the temperatures of the *wet-bulb and dry-bulb thermometers.*

---

[1] e.g. *The Meteorological Observers' Handbook* or *The Air Ministry Hygrometric Tables.*

(iii) *Wet-bulb and dry-bulb thermometers.*—This is the simplest instrument for measuring humidity. It depends on the principle of cooling by evaporation. To show how the instrument works, take two similar Fahrenheit thermometers and hang them up side by side *in a current of air*. Wrap a piece of cotton cloth round the bulb of one thermometer and allow the free end to dip into water so as to keep the bulb wet, as shown in Fig. 112. If the surrounding air is not saturated, water will evaporate from around the wet bulb and the necessary *latent heat* (see p. 276) will be taken from the thermometer bulb. In this way, if the air is not saturated with water-vapour, the wet-bulb thermometer will show a lower temperature than the dry-bulb thermometer. If the air is already saturated with water, then there can be no evaporation from the wet-bulb and there will be no fall in temperature, so that both thermometers will show the same reading. If the air is very dry, then there will be rapid evaporation from around the wet-bulb and the readings of the wet-bulb thermometer will be much lower than those of the dry-bulb thermometer. Set up a wet-bulb, dry-bulb thermometer in your class-room and take daily readings throughout the school year.

(iv) *Relative humidity.*—The commonest way of expressing humidity is by stating the *relative humidity*, i.e. the degree of saturation (expressed as a percentage) at any given temperature.

$$\text{RELATIVE HUMIDITY} = \frac{\text{QUANTITY OF WATER ACTUALLY PRESENT}}{\text{QUANTITY REQUIRED TO SATURATE THE AIR}}$$

at the same temperature

You can find the relative humidity, if you have read the wet-bulb and dry-bulb thermometers, by looking up tables[1] giving relative humidity and vapour-pressure for any pair of wet-bulb and dry-bulb readings. If the relative humidity is high, the air feels damp; if the relative humidity is low, the air feels dry. In many tropical countries where the relative humidity is high, rooms and buildings are now '*air-conditioned*'. This is done by passing the incoming air over cooled surfaces so that some of the water-vapour is condensed. This drier air is then circulated round the room or building, producing a marked cooling effect on the skin.

[1] e.g. *The Meteorological Observers' Handbook* or *The Air Ministry Hygrometric Tables.*

APPENDIX D

NOTE ON THE EFFECTS OF ALCOHOL UPON THE HUMAN BODY

The effects of alcohol upon the body have been summarized by a British Royal Commission as follows:

(1) Alcohol is primarily a *drug* acting directly on the nerve centres.

(2) Alcohol is *not* a stimulant, but it is essentially a *narcotic* (i.e. it brings about sleepiness or even insensibility).

(3) When taken in excess, alcohol acts as a *poison* (like any other drug); and if taken habitually in excess alcohol may cause, or help to cause, a variety of diseases.

(4) The drug or poison action of alcohol is considerably reduced when it is taken in dilute solution or with food.

(5) Alcohol has some food, or fuel, value but any such value is largely offset by the disadvantages of its drug action.

(6) The use of alcohol as an aid to work, whether physical or mental, is scientifically unsound.

(7) Alcohol has no value for preventing or curing disease (although within a strictly limited range of conditions and under medical supervision it has a place in medical treatment).

GLOSSARY

Scientific words whose meaning is explained in the text are listed in the Index.

abattoir, place built for the killing of animals for food.

abnormal, not *normal*.

abscess, collection of *pus* formed in a *cavity* in the body-*tissues*.

absorb, take in or suck up.

abundant, plentiful.

accessory, additional.

accumulate, collect together, heap up, form a heap.

accurate, exact.

achieve, reach, gain something aimed at.

acquire, gain by oneself and for oneself.

adapt, make fit or suitable.

adequate, sufficient for requirements.

adjust, fit one part to another; *alter* slightly.

adult, grown-up person.

alcohol, spirit of wine.

alkalis, substances which have a bitter or soapy taste and which change the colour of *litmus* from red to blue: they *neutralize* acids.

alter, make or become different; change.

alternate, first one and then the other.

amazing, astonishing.

ambulance, *vehicle* for carrying sick or wounded persons.

analyse, find out the *elements* of; separate into simpler parts. (*n.*), *analysis*.

ancestor, any one of those persons from whom one's father or mother is descended.

ankle, joint connecting foot with leg.

anti-, against, opposite.

antiseptic, substance that stops the growth of *bacteria*.

apex, tip, pointed end.

appetizing, causing desire to eat; (*n.*), *appetite*.

appreciate, set high value on.

approximate, not exact.

aquatic, growing or living in or near water.

arch, curved *structure* supporting the foot, or a bridge, wall or floor.

aspect, way a thing presents itself to the eye or the mind.

athlete, one who competes or excels in physical exercises.

atmosphere, *layer* of air, many miles thick, which surrounds the earth.

atom, the smallest *particle* of an *element* that can take part in a *chemical* change.

attach, fasten, cause to stick.

auger, tool with screw-point for *boring* deep holes.

automatic, working of itself, self-acting.

available, able to be used, within one's reach.

axis, line dividing a regular figure into two parts exactly similar in shape and size; *core* of *organ* or *organism*.

bacteria, germs: extremely small living things; some kinds cause disease and decay; others turn sugary liquids sour; (*sing.*, bacterium).

balloon, air-tight bag usually filled with a gas which is lighter than air.

bandage, long white cloth for covering a wound; also (*v.*) apply a bandage.

barometer, instrument for measuring air-pressure.

base (*n.*), in *chemistry*, a base is a substance that reacts with an acid to form a salt and water.

barracks, building for housing soldiers.

beaker, wide-mouthed glass vessel used in *laboratories*.

belly, lower front part of the trunk, including the stomach.

benefit (*n.*), advantage.

benign (of illness), not of a dangerous type.

biceps, a *muscle* having two points of *attachment*.

bile, bitter juice produced by *liver* to help *digestion*.

biology, science of life of animals and plants.

biscuit, small thin cakes made chiefly of flour and water and baked hard.

bladder, bag-like container (here) of *urine* or *bile*.

blanket, large woollen bed-covering.

bleach, whiten by *exposure* to sunlight or certain chemicals.

blister, a watery swelling under the skin caused by burns, rubbing, etc.

blunder, move about blindly.

boil (medical), hard swelling of the skin, larger than a *pimple* and filled with *pus*.

bore (*v.*), make a hole in.

bore (*n.*), *internal diameter* of tube or pipe, its *calibre*.

bounce, spring back.

bowel, any part of food-canal below stomach.

breed, have young ones, reproduce.

breeze, gentle wind.

brine, *solution* of common salt in water.

bristle, short stiff hair of pig and some other mammals.

brittle, hard but easily broken.

bubble, ball of liquid enclosing air.

bucket, container for carrying water by hand.

bulb, roundish swelling (e.g. at end of glass tube).

bulk, size or mass or volume.

cable (electrical), line containing a number of wires *insulated* from one another.

calf (animal), young cow or bull.

calf (of leg), fleshy part at back of leg below knee.

calibre, see *bore* (*n.*).

calorie (or *gram-calorie*), the scientific unit of heat *energy* (see p. 275); 1 *kilo-calorie* = 1,000 *gram-calories*.

calorific value, ability to produce heat-*energy*.

calorimeter, vessel in which heat-measurements are made.

cane (*n.*), hollow woody stem, e.g. thin bamboo.

canvas, coarse cloth.

capable, able.

capacity, holding-power, receiving-power, volume, ability.

capillary (*adj.* and *n.*), very fine, hair-like (tube or blood-vessel).

capsule, (here) enclosing *membrane*.

catch (*n.*), door-fastening.

cavity, hollow within a solid body.

cells, the units of which all living things are built.

cellulose (*n.*), substance forming cell-walls of plants.

cement—concrete, building material used as a wet paste which hardens into rock-like solid.

cereal, eatable kind of grain, e.g. rice, millet, wheat, barley.

chamber, enclosed space in body of animal or plant; room.

charcoal, black *porous residue* left after heating wood in absence of air.

check (*v.*), cause to go slow or stop.

chemical (*n.*), any substance obtained by, or used in, *chemistry*; (*adj.*), of or made by chemistry.

chemistry, science treating behaviour

of *elements* in their various *combinations.*

chew, work food about between the teeth in order to crush it.

chill (*v.*), make cold.

chipped, with broken edges.

choke (*v.*), be unable to breathe or stop the breathing of.

circulation (of the blood), movement of blood to and from the heart and round the body.

circumference, line enclosing circle.

circumstances, *external* conditions.

clad, clothed.

clamps (*n.*), apparatus for holding something in one position, tightened by screw or spring.

classify, *classification*, arrange(ment) in classes.

claw, pointed nail of bird's or beast's foot.

clinic, part of hospital where advice and treatment are given (usually free).

clip (*n.*), small apparatus for holding things together, usually worked by a spring.

clot, (form into) half-solid lump(s) (of blood, cream, etc.).

clump (together), form close group or *cluster*.

cluster (*v.*), form close group of like things.

coil (*n.*), length of thread-like material arranged in circles.

collapse, sudden failure or breakdown.

column, long upright *cylinder* of stone, etc., supporting building; anything of that shape and *function*, e.g. *spinal column*.

combine (chemical), join together to form a chemical *compound*. (*n.*), *combination*.

combustion, burning.

communal, belonging equally to all the people living in one district and having common interests, i.e. belonging to the *community*.

communicable, able to be passed on, or *communicated*.

compact (*adj.*), closely packed together.

comparative, compared to.

compartment, *chamber*.

compel, force (to do something).

complex, made up of parts.

compost, an *organic manure* made by decay of plant and animal material.

compound (chemical), substance resulting from *chemical combination* between two or more *elements*.

compound, enclosure in which house or factory stands.

compulsory, enforced, *compelled*.

concave, curving inwards; opposite of *convex*.

concentrate, (here) increase strength of (*solution*, etc.) by *contracting* its volume.

conclude, *conclusion*, judge(ment).

condense (chemical), change from gas to liquid; reduce volume by *evaporation*.

conduction, the *process* by which heat travels through matter.

conservation, preservation.

constant, not varying.

constituents, parts making up the whole.

consult, ask guidance or opinion from.

consumer, user of product.

contact, state of touching.

contaminated, made impure, *infected*.

contract (*v.*), become or make smaller.

contrast, marked difference.

convection, the *process* by which heat is conveyed by moving gas or liquid.

converge, move in the direction of meeting at a point.

converse, turned round or upside down.

conversely, the other way round.

convert (*v.*), change (from one form into another).

convex, curving outwards; opposite of *concave*.

co-operation, working together for one purpose; *team*-work.

co-ordination, the act of bringing into proper relation.

core, central portion.

corpuscles, tiny *cells* forming a large part of the blood.

corresponding, similar, agreeing in kind.

create, make; bring into existence.

crop, (here) bag-like enlargement of *gullet* in birds, insects, &c. where food is prepared for *digestion*.

crucible, vessel (e.g. of fireclay) that can be heated very strongly without melting.

crude, in a natural or raw state.

crumbly, easily broken into *crumbs* (like dry bread).

crust, hard, dry formation on the skin; *also* hard outer part of bread.

crystals, particles of definite regular shape enclosed by *plane* surfaces.

culture, a cultivation of *bacteria*.

curd, *clot* of substance formed, e.g. when milk goes sour.

curry, hot-tasting dish of meat, &c.

cylinder, solid or hollow object shaped like a roller.

dairy, place where milk is dealt with, milk-shop.

decompose, (cause to) decay or split up into simpler substances.

decrease, lessen.

defect (*n.*), failing.

deficiency, want, lack.

define, give exact meaning of.

definite, with exact limits, *distinct*.

demonstrate, describe and explain with help of experiments.

dense, closely-packed.

dental, of the teeth.

dentist, tooth-doctor.

deposit (*v.*), lay down (something) in a place; (*n.*), layer of matter *deposited* by nature.

derive (from), obtain from.

desiccation, removal of all water from something, drying up.

design, plan.

detect, discover the presence or nature of.

determine, find out or fix *accurately*.

device (*n.*), apparatus *designed* for a particular purpose.

devoid (of), quite free from.

devote, set aside entirely for one purpose.

dew, tiny drops of water *condensed* on a cold surface.

diagonal, slanting line drawn from corner to corner of straight-sided geometrical figure.

diagram, simple outline drawing.

diameter, line drawn across circle through its centre.

diet (*n.*), habitual food, feeding-plan.

diffuse (*v.*), spread by mixing (gases or liquids).

digest, change food in the body so that it can be *absorbed*; *digestive*, concerning or helping digestion.

dilute (*v.* and *adj.*), reduce(d) in strength by adding water.

diminish, make or become less, either actually or in appearance.

discharge, send out (heat, electricity, etc.).

disinfectant, substance which destroys germs and makes free from *infection*.

dislocate, force bones of the body out of their proper positions.

disorder (medical), *abnormal* action or working.

dispensary, place where *dispenser* makes up and gives out medicines.

displace, take place of, drive out.

dispose, put away, get rid of, (*n.*), *disposal*.

dissect, cut up (animal or plant), take to pieces, examine.

distinct, plain, separate, unlike, *definite*.

distribute, put at different points; spread out.

diverge, move in different directions spreading out from a point (opp., *converge*).

donor, giver.
dose, amount of medicine to be taken at one time.
dough, flour *moistened* and *kneaded.*
drain (*v.*), carry away water and other liquids by a channel or *drain* (*n.*); *drainage* (*n.*), what has been drained.
draught, current of air between openings in room, &c.
droplet, a very tiny drop.
drug (*n.*), medicinal substance.
duct, fine tube in the body carrying liquid.
dump (*n.*), heap of useless earth, &c.; (*v.*), *deposit* this.
dustbin, container for dirt, rubbish, &c.
dwarf, person, animal or plant much below *normal* size.
dye (*n.*), colouring-matter that can be taken up and held by other materials, changing their colour *permanently.*
dynamite, a powerful explosive substance.

earthenware, article of baked clay.
edible, fit to be eaten.
effective, producing desired effect.
elbow, outer part of middle joint of arm; corner or bend shaped like elbow.
element, substance which has never been split up into two or more simpler substances by *chemical* action.
elementary, not developed; simple.
embryo, young, partly-developed plant or animal.
emerge, come into view.
emotion, *mental* feeling, state of mind.
encourage, make bold, urge.
energy, a body's power of doing work by moving &c.; capacity for work.
engage, employ.
enormous, very large.
epidemic, disease which is widespread for a time.
essential, necessary; most important.
estimate (*v.*), form a judgement of number, amount, &c.; (*n.*), quantity thus arrived at.
evacuate, empty out, *discharge.*
evaporate, change into *vapour* or gas without boiling.
evidence, facts which give reason for believing something.
exclude, shut out.
excreta, *faeces* and *urine.*
excretory, for getting rid of waste-matter from the body-cells.
exert, bring into use; use one's strength to do something.
exhaustion, state of being tired out or used up.
expand, increase in size, swell.
expert (*adj.*), practised, skilful; (*n.*), person *expert* in subject.
expire, breathe out (opp., *inspire*).
expose, bring to view, uncover.
external, outside (opp., *internal*).
extract (*v.*), take out by force; (*n.*), preparation of a substance in *concentrated* form.
extravagant, beyond reason, wild; wasteful.

factor, fact or circumstance helping to bring about a result.
faeces, solid food-waste from animal's body, droppings.
famine, extreme scarcity of food.
fatal, ending in death.
fatigue, tiredness.
feature, characteristic part.
fermentation, process like that produced by *yeast* in *dough*, or by yeast in sugary liquids (producing *alcohol*).
fertilize, make fertile, make to produce *offspring*.
fever, condition in which body-temperature is above normal.
fibre, thread; *fibrous*, threadlike.
filter (*n.*), apparatus for freeing a liquid from solid particles held by it. *filtrate* (*n.*), the liquid after separation of the solid particles from it.

filth, disgusting dirt.

fin, fish's swimming and steering *organ*.

finally, as the last result or act.

fist, the hand when tightly closed.

flakes, very thin broad pieces.

flange, *projecting* collar round a wheel or the end of a tube or pipe.

flap (*n.*), hanging piece held by one side.

flexible, that bends without breaking.

fluid, material that flows freely, i.e. liquid or gas; not a solid.

flush, (of blood) rush into blood-vessels of skin.

focus (*n.*), point at which light-rays meet after reflection from a curved *mirror* or after being bent by passing through a *lens*; (*v.*), *converge* to a *focus*.

foil (*n.*), metal hammered or rolled into a very thin sheet.

forceps, pinchers (or pincers) for picking up small objects.

formulate, express clearly in a set form of words (or *formula*).

fore, in front; front part.

foul, dirty, unhealthy, bad-smelling.

fraction, number that is not a whole number—½, ¾, ⅝, &c.

fracture (*n.*), breakage (usually of bone).

friction, rubbing of one thing against another.

fry, cook in boiling fat.

fuel, material for fires (coal, wood, oil).

function, special activity or purpose of a person or thing; action by which anything carries out its purpose.

fundamental, forming a foundation, essential.

fungi, flowerless, non-green plants; (singular, *fungus*).

funnel, Y-shaped vessel for pouring liquid into a small opening.

fuse (*v.*), (here) unite together.

galvanized iron, iron coated with zinc.

garment, article of clothing.

gastric, of the stomach.

gauze, thin, almost transparent, woven material of cotton, wire, &c.

generation, all persons born about the same time; average time in which children are ready to replace parents (about 30 yrs.).

germicide (*n.*), substance that kills germs.

germinate, begin to grow from seed.

giant, unusually tall and big person, animal or plant.

girdle, belt, thing that surrounds.

gland, kind of *organ* forming, holding and giving out, e.g. digestive juices, milk, &c.

glaze, give a shiny *transparent* coating to; *unglazed*, in the rough state before glazing.

glove, hand-covering.

gnaw, bite repeatedly, as a mouse does.

grade (*n.*), degree in rank or class.

graduate (*v.*), mark out in degrees or parts.

grasp (*v.*), hold firmly.

gravity, attractive force by which a body is drawn towards the centre of the earth.

gravy, juices that *ooze* from meat during cooking; food dressing made from these juices.

graze, (of cattle) feed on grass; (of skin) scrape skin in rubbing past rough object or material.

gristle, tough *flexible tissue* or *cartilage*.

groove, hollow channel in the surface of anything.

gullet, food-passage from mouth to stomach, *oesophagus*.

gum (dental), firm flesh in which the teeth stand.

gut, food-canal below the stomach; the *intestines*.

handicap (*n.*), disadvantage; (*v.*), place (person) at disadvantage.

harbour (*v.*), give shelter to.

hatch, break or come out of an egg.

hawker, person that carries around articles for sale from house to house.

hence, as a result of this; therefore.

hepatic, of the *liver*.

herbage, soft-stemmed plants; non-woody plants.

hibernate, spend cold season in state of greatly reduced activity.

hind, situated at the back or tail end of an animal.

hinge (*v.* and *n.*), (attach with) movable joint like that by which a door is hung.

hip, *projection* where head of *thigh*-bone joins bones of trunk just below waist.

hobby, favourite subject or occupation which is not one's main business.

honey, sugary liquid prepared by bees and stored in *cells* of *honey-comb*.

horny, like the fingernails or the hard growths on the heads of cattle.

host, one who entertains a guest; animal or plant *harbouring parasites*.

humidity, dampness.

husk, hard outer covering of seed, &c.

hygiene, the science of health.

identify, recognize or prove as being a certain person or thing.

ignorant, lacking knowledge.

image, (here) imitation of an object's *external* form produced by *mirror* or *lens*.

immune, protected against, unaffected by.

import (*v.*), bring goods into a country from outside; (*n. pl.*) the goods brought in.

impulse, driving-power, *stimulus*.

incinerator, enclosed fire-place for burning rubbish.

index (finger), fore-finger; finger one uses to point out anything.

indicator, something that *indicates*, points out, shows.

individual (*n.*), one single person; (*adj.*), single.

infant, (here) child under seven years of age.

infect, (of person) give disease to; (of things) able to give disease by having been in touch with diseased person.

inferior, of poor quality; situated below (opp., *superior*).

inhabit, live in.

inherit, receive (characteristics, property, &c.) from parents and ancestors.

inject, force (liquid) into a cavity.

injure, do harm to.

inorganic, (of *minerals*) not *organic*.

insanitary, not healthy, especially with regard to dirt and *infection*.

insecticide, substance that kills insects.

insoluble, unable to dissolve, not *soluble*.

inspect, look closely into. (*n.*), *inspection*.

inspire, breathe in (opp., *expire*).

instinct, natural tendency to behave in a certain way without reasoning.

insulate, cut off from outside influence (usually from heat exchange or from electrical effects); *isolate*.

intelligent, having, showing, a high degree of understanding; basing actions on reason and not merely on *instinct*.

intermediate, situated or coming between (in time, space, degree, &c.).

internal, of or in the inside (opp., *external*).

interval, time or space between one event or object and another.

intestine, lower part of food-canal, below the stomach.

intoxicated, overcome by strong drink containing alcohol.

invert, turn upside down.

investigate, inquire into, examine.

involuntary, not controlled by the will (opp., *voluntary*).

involved, being concerned with or included in something.

irrigation, supplying crops with water through pipes or channels.

irritation, uneasy *sensation* caused by *stimulus*.

isolate, place apart or alone, *quarantine*.

itch (*v*. and *n*.), (have) uneasy *sensation* in the skin causing desire to scratch.

jar (*n*.), deep round vessel of glass or *earthenware*.

jelly, an elastic, non-*rigid* solid, e.g. *gelatine*.

jerk (*n*.), sharp sudden pull, twist, or throw.

job, piece of work.

jungle, thick tropical forest.

kerosene, lamp-oil or *fuel*-oil obtained from oil-wells.

kidneys, pair of *organs* in mammals, birds, and reptiles, for *excreting* urine, &c.

kitten, young cat.

knead, mix flour and water by working with the hands to form *dough*.

laboratory, science workroom.

labour, work, pieces of heavy work.

lactate (*v*.), produce milk from milk-*glands*.

larva, pl. *larvae*, insect, from time of leaving egg until it becomes a *pupa*.

latent heat, the number of *calories* required to change one gram of a substance from the solid state to the liquid state, or from the liquid state to the gaseous state, or *vice versa*, without changing temperature.

laterite, product from weathering of granite rock in wet tropics.

lather, mass of small *bubbles* or froth.

layer, thickness of matter, especially one of several, spread over a surface.

leak (*n*.), hole or passage through which fluid wrongly makes its way out; (*v*.), pass out through *leak*.

lean (of *meat*), not fat.

legume, *leguminous* plant bearing seed in *pod*.

lens, glass giving a larger or smaller view of an object.

lenticels, small openings in non-green parts of plants.

leper, person suffering from *leprosy*, a serious skin disease.

lever, bar on a fixed support on which it is turned from one end in order, for example, to exert force at the other end.

liable (to), exposed to, open to.

linen, cloth made from flax-plant *fibres*.

link (*n*.), one ring of a chain.

litmus, blue vegetable colouring-matter that turns red with acids and blue again with *alkalis*.

litre, unit of *capacity* in Metric System about 1¾ pints.

loop, closed figure made by curve that crosses itself.

lubricate, oil or grease (machinery), make slippery.

lungs, the two air bags in the chest, used in breathing.

lymph, colourless liquid which bathes tissues, like blood but without red *corpuscles*.

maggot, fly-*larva*.

magnify, make appear larger than the real size.

maintain, keep up.

major (*adj*.), of the greater, more important, kind (opp., *minor*).

majority, the greater number, more than half (opp., *minority*).

malignant (of illness), of a dangerous type (opp., *benign*).

mammal, warm-blooded hairy animal fed on milk by the mother when young.

mangrove, tropical tree growing in *swamps*.

manure, animal droppings used as fertilizer.

margin, border, strip around the edge of something.

marrow, fatty substance in *cavity* of bones.
marshy, continually wet and muddy land.
mat, piece of coarse material laid on floor.
mate (*v.*), pair off for *breeding*.
maximum, greatest possible quantity or size (opp., *minimum*).
measure, (here) *precaution*, planned action to gain object.
mechanism, way a machine works.
membrane, thin flexible sheet of *tissue* lining or connecting parts of body.
mental, of the mind.
micro-, extremely small.
microbe, extremely small animal or plant.
microscope, instrument using *lenses* to enlarge the appearance of extremely small objects.
mild, gentle, not severe.
mineral, (*inorganic* substance) obtained from the earth.
minimum, least possible quantity or size (opp., *maximum*).
minor (*adj.*), of the smaller, less important, kind (opp., *major*).
minus, the sign — for taking away a quantity.
minute (*adj.*), very small.
miracle, remarkable event.
miraculous, wonderful.
mirror, polished surface that reflects light; looking-glass.
mite, kinds of very tiny animal living on other animals or plants.
modify, make some changes in.
moisten, make slightly wet, make damp. (*n.*), *moisture*; (*adj.*), *moist*.
molecule, the smallest *particle* of a substance that can exist in a free state, by itself.
motion, (here) emptying of the large intestine.
motor (*adj.*), (of a muscle or nerve) producing movement.
mound, heap of earth.
municipality, town with local self-government. *municipal*, of or carried on by a municipality.
muscle, lean flesh or meat, animal *tissue* that produces movement by *contracting*.
mutton, meat of sheep or goat.
muzzle, a little cage put over an animal's head to prevent it biting, eating, etc.

naked (eye), unassisted by *optical* instruments.
navy, a country's warships with their officers and men.
nectar, sugary liquid produced by flowers and made into *honey* by bees.
negative, opposite of *positive*; less than zero; shown by the *minus* sign —.
nervous system, consisting of the brain, the spinal cord and the nerves, by which the body is directed and controlled.
neutralize (*v.*), make chemically *neutral*, neither acid nor *alkaline*.
nodule, small rounded lump.
normal, usual, regular, ordinary (opp., *abnormal*).
nostril, nose-hole.
nucleus, central part.
numerous, many, a large number of.
nutrient (*n.*), substance used for *nutrition*.
nutrition, the feeding process in animals and plants.

obstacle, a bar to progress or success; *obstruction*.
obvious, easily seen or understood; plain; clear.
oesophagus, *gullet*.
occupation, employment.
offspring, the young of animals (before and soon after birth).
ooze (*v.*), flow out slowly (through *pores*).
optical, of the sense of sight.

organ, part of animal or vegetable body performing a special *function*.

organic, having organs; to do with plants or animals; not *mineral*.

organism, a living animal or plant.

oval, egg-shaped.

ovary, female egg-producing *organ*.

oven, enclosed box-like space which is heated for baking food.

overlap, partly cover; cover and extend beyond.

oviduct, *duct* by which egg-cell leaves *ovary*.

oxidation, combination with oxygen.

palm, (here) inner surface of hand between wrist and fingers.

pant (*v.*), breathe quickly and noisily.

paradise, heaven.

paraffin, mineral oil, *kerosene*.

parallel, continuously the same distance apart.

paralysed, unable to feel or move owing to failure of nerve-action.

parasite, an animal or plant which lives in or on another *organism* and feeds on it. (*adj.*), *parasitic*.

parboil, half cook by boiling.

particles, very small bits of matter.

partner, one of a pair that shares work or other activity.

passive, acted upon, not active.

pastry, baked flour-paste.

patent-medicine, medicine sold commercially and *patented* or protected from imitation by other chemists.

patient (*n.*), person who is ill and under a doctor's care.

pea, seed of *leguminous* plant bearing round seeds in *pods*.

peel (*v.*), take off outer skin.

pellet, small ball of material; *pill*.

period, any length of time.

permanent, lasting, not *temporary*.

persistent, continuing to exist or do something in spite of *obstacles*.

petroleum, mineral oil from which *petrol*, *paraffin*, &c. are obtained.

petrol, purified *petroleum* used in motor-cars; *gasoline*, *benzine*.

philosopher, a student of *fundamental principles*, particularly of Nature and the meaning of existence.

physics, science that deals with the qualities of matter and energy.

physical, belonging to *physics* as distinct from *chemistry*.

pickle (*v.*), preserve in *brine* or *vinegar*.

pierce (of sharp-pointed instruments), go into or through; make a hole by doing this.

pill, small ball of medicinal substance for swallowing whole.

pillow, cushion on which head rests (especially in bed).

pimple, small swelling of the skin, sometimes containing *pus*.

pit, deep hollow in ground or in skin (e.g. hair-pit).

pit latrine, hole dug to receive *faeces*.

pitch, black waterproof solid obtained from coal or oil.

pitch (of music), that which distinguishes a 'high' note from a 'low' note.

plane (*adj.*), smooth or level.

platform, level surface raised above surrounding ground.

plug (*n.*), something fitting into and filling a hole; (*v.*), stop with a *plug*.

pod, long seed-case, e.g. fruit of pea, bean.

polish (*v.*), make bright.

pond, pool.

population, the people of a town or country, the number of persons in a town or country.

porcelain, very fine clay (pottery).

pore, ***sweat-pore***, very small opening (as in skin) through which fluids may pass.

pork, meat of the pig.

porous, full of *pores*.

positive, (here) showing the presence of some quality or *constituent*.

posture, position of the body.

pound (*v.*), crush to powder.
practical, concerned with action rather than *theory*.
precaution, care taken in advance to avoid harm or risk.
precipitate (*n.*), solid matter thrown down from a *solution* when suitable chemical *reagent* is added.
precise, exact.
pregnant, (of a woman) being about to give birth to a child.
prescribe (medical), advise use of medicine or treatment.
prick (*v.*), make tiny hole, hurt with a sharp point.
primary, holding first place in importance or in time.
primitive, of a simple, early, undeveloped kind.
principle, law of science, rule.
process, course of action, method of manufacture.
project (*v.*), stand out beyond the surface near-by.
prolong (*v.*), make longer, cause to continue.
prominent, *projecting*, standing out distinctly.
proportion, part of a whole, especially compared with other parts; relation between two things in size, &c.
pulley, *grooved* wheel that changes direction of pull in the string running in the groove.
pulp, soft part of fruit; any other soft, damp, formless matter.
pulse, each beat of arteries or heart.
pulse (crop), seeds of pod-bearing plant, e.g. peas, beans, lentils.
pungent, with stinging smell or taste.
pupa, resting-stage in insect's life-history while *larva* is changing into an adult insect.
pus, thick yellow matter found in *sore* places.

quarantine, separation (of sick persons, &c.) from others; isolation.
quench (*v.*), satisfy thirst.

radiation, the transfer of heat independently of matter without physical contact.
ratio, comparison between two numbers or quantities. Thus 30 and 5 are in the ratio of 6 to 1.
ration, fixed daily allowance of food.
reaction, effect produced by chemical *reagent*.
reagent, substance that *reacts* upon another and can therefore be used to discover its presence.
rectum, lower part of large intestine.
recur (*v.*), come up again, be repeated. (*adj.*), *recurrent*.
refrigerator, apparatus for making and keeping food cold.
refuge (*n.*), shelter from danger; *refugee*, person taking refuge abroad from danger or trouble at home.
refuse (*n.*), rubbish; that which is thrown out as worthless.
registration, official recording.
relative (*adj.*), comparative.
relapse, fall back into worse state after improvement.
relax, allow to become loose or less stiff.
release, set free, unfasten (from), let go.
remove, take off, take away, get rid of.
reproduce, produce young.
reservoir, place for storing a large quantity of water.
residue, substance that remains behind.
resonance, the principle of co-*vibration*, where small forces, properly 'in step', will set up much bigger vibrations in neighbouring objects; *resonate* (*v.*), vibrate 'in step' with.
respiratory, for breathing.
respond, act in answer, make answer.
restrict, limit.
revolutionize, completely change or reconstruct.
rib, one of the bones that form the chest.

ridge, line where two sloping surfaces meet, as on top of a roof.

rifle, (hand-gun with) *spiral groove* inside barrel for spinning the bullet.

rigid, quite stiff.

rinse, wash lightly with clean water to clear soap and dirt away.

roam, wander here and there about the country.

roast, cook without water in the heat of an open fire, or in an oven.

rock (*v.*), shake gently from side to side.

rug, floor-mat of thick woollen material.

sac, bag-like *cavity* in animal.

safe (*n.*), (here) *ventilated* fly-proof cupboard for food.

salad, vegetables prepared as food without cooking them.

saliva, the digestive liquid present in one's mouth.

sandals, shoes with open sides.

sanitary, healthy with regard to the treatment of dirt and *infection*; connected with *sanitation*.

sanitation, improving of conditions having an effect on health, particularly removal of dirt and *faeces*.

sap, juice of plants.

saturate (*v.*), cause to *absorb* the greatest possible amount of another substance.

scale, (here) one of the hard dry pieces of skin formed in certain diseases, like the thin flat plates covering the skin of some fishes.

scalpel, a small sharp knife used in *dissection*.

screen, frame covered with metal netting, etc., for separating liquid from solid, solids of various sizes, &c.

scrub (*v.*), rub hard to clean, especially by applying soap and water with a hard brush.

scrub (*n.*), ground covered with small trees and bushes.

scrupulous, careful of small details.

scum, impurities that rise to the surface of liquid.

seal (*v.*), close tightly, e.g. so as to keep air or water from passing.

section, cutting; *cross-section*, area uncovered by cutting straight across an object.

secure (*v.*), make safe.

sedentary (work), done sitting down.

sediment, solid matter that settles to bottom of liquid.

sedimentation, process during which *sediment* falls to bottom.

see-saw, strong board balanced on a raised support in the centre.

segment, part marked off separately, e.g. one ring of earth-worm.

select, pick out, choose.

sensation, *consciousness* of something affecting the body or its parts.

sensitive to, readily affected by *stimulus*.

sense-organ, organ for feeling, seeing, hearing, tasting or smelling.

sensory, concerned with *sensation*.

septic (*adj.*), *infected* with harmful germs; not *aseptic*; *sepsis* (*n.*), septic condition.

series, set of similar or related things.

serum, watery part of blood.

sewage, *excreta* mixed with waste water and carried in *sewers*.

sewer, covered underground drain carrying *sewage*.

shavings, thin *slices* shaved off from a solid block.

shiver, tremble with cold.

sieve (*n.*), wire *gauze* for separating smaller from larger particles by shaking them through the small holes in the gauze.

significant, having a definite meaning; important.

skeleton, framework of bones. (*adj.*), *skeletal*.

skim (*v.*), take *scum* or cream from surface of liquid.

skip (*v.*), jump lightly up and down.
skull, bony brain-case; the bones of the head.
slab, flat piece of *rigid* material (e.g. concrete).
slice, thin broad piece (of bread, meat, &c.) cut off.
slime, soft slippery mud or substance similar to it.
sling (*n.*), bandage passing over shoulder to support injured arm or *hand*.
slit, long cut or opening; also (*v.*), make a slit.
sluggish, slow-moving.
social, concerned with living in *communities*.
socket, hollow for something to fit into or revolve in.
soluble, able to *dissolve* and form a *solution*; (not *insoluble*).
solution, liquid mixture formed by *dissolving*.
soot, carbon, black powdery substance, produced by burning coal, &c.
sore (*n.*), place on or in body where skin or *tissue* has been broken.
sparkle, give out small bright moving points of light.
species, class of things with some common characteristics.
speck, small spot or *particle*.
spectacles, pair of *lenses* supported in front of the eyes to assist them to see better.
sperms, male reproductive cells.
spherical, shaped like a ball or *sphere*.
spinal cord, a central part of the nervous system running down the middle of the back-bone.
spine, back-bone.
spiral, winding round in the shape of a *coil*.
spit, force (*saliva*, *spittle*, *sputum*) out of the mouth.
splint, piece of wood bound to limb to hold broken bone in proper position while it sets.
splinter, sharp-pointed thin piece of wood split off from board, &c.
spongy, elastic, *porous*, and *absorbent* as a *sponge* used in bathing the body.
spore, single cell from which a new plant or animal can grow.
spray, (*v.*) force liquid into the air in fine drops; (*n.*) apparatus for doing this.
sprinkle, scatter in small drops or particles.
spurt, burst forth, shoot out, *squirt* out.
sputum, fluid spat out from mouth; *spittle*.
squat (*v.*), sit on one's heels.
squeak, short high-pitched sound or cry.
squeeze, apply pressure to.
squirt, *spurt*.
stable (*adj.*), not liable to change (opp., *unstable*).
stall, open-fronted shop.
statistics, numerical facts systematically collected and arranged.
sterilize, make *sterile*, i.e. free from living germs.
stew (*v.*), cook by long gentle boiling in closed vessel with little liquid.
sticking-plaster, cotton or linen material spread with sticky substance and applied to skin to cover wounds or to hold dressings.
stimulate, apply a *stimulus*, act as a *stimulus*.
stimulus, thing that brings about a *response*.
stink, *foul* smell, disgusting smell.
stoker, man who *stokes* fire under boiler by feeding it with *fuel*.
stoma, *stomate*, tiny opening in skin of leaves and other green parts of plants.
stoop, carry one's head and shoulders bowed forward.
strenuous, making or requiring great effort.
structure, framework, way in which a thing is *constructed* or fitted together.

subject (*v.*), expose (to).

subsequent, following the event.

subsoil, layer of soil lying immediately under the surface soil.

substitute, put in exchange for.

sufficient, enough.

suggest, cause (idea) to present itself.

summarize, make a short account of, make a *summary*.

supervise, oversee, watch or direct the work of.

surgeon, doctor skilled in curing by *surgical* method, i.e. operation or cutting.

survive, outlive, come safely through.

suspect, think that something is wrong; *suspicion* (*n.*), feeling that something is wrong.

suspend, hang from; *suspended* (of solid *particles* in liquids), *in suspension*, somewhere between surface and bottom.

sustain, keep up the strength, enable to last out.

swamp, wet spongy ground, *marsh*.

symbol, mark used to represent something, e.g. letters of the alphabet; letters used to represent chemical *elements*.

sympathy, fellow-feeling, being affected similarly to another by his *sensations*.

symptom, sign of existence of disease or *disorder* in the body.

synthesize, put together, cause elements to combine (opp., *analyse*).

synthetic, formed by *synthesis*.

syringe (*n.* and *v.*), *spray*, *squirt*.

table-ware, dishes, &c., used at meal-times.

tadpole, *larva* of frog.

talcum, powdered *talc* or soapstone.

tank, large container for liquid or gas.

tape, narrow strips of cloth.

team, a side of players *co-operating* together.

teats, (here) part of cow's *udder*.

temperate, (here) neither very warm nor very cold.

temple, (here) flat part at side of head between forehead and ear.

temporary, not lasting (opp., *permanent*).

tend to, be moving or straining (towards the result stated).

tension, effect produced by forces pulling against each other.

termite, an ant-like insect that destroys wood; 'white ant'.

tertian, (fever) which becomes severe every other day.

thatch, roof-covering of straw, grass or leaves.

theory, rules and principles as distinguished from practice.

theoretical, concerned with *theory*, not *practical* or *experimental*.

thigh, part of human leg between hip and knee.

thorax, part of the *trunk* between the neck and the belly.

tile, thin piece of baked clay for covering roofs or making floors.

tissue, a mass of cells of the same kind, such as muscle-tissue, nerve-tissue, &c.

tourniquet, instrument for stopping the flow of blood through an artery.

toxin, a poison; especially one produced by a germ and causing some particular disease.

trachea, wind-pipe.

tract, part of body performing some special *function*.

transfer, carry from one position or container to another.

transform, make change in form.

transfuse, *inject* blood or other liquid into veins. (*n.*), *transfusion*.

translucent, *transmitting* light but not *transparent*.

transmit, pass on.

transparent, that can be clearly seen through.

transpire, pass out water-*vapour*.
transport, carry from one place to another.
transverse, lying or placed across, stretching across.
trench, ditch.
triangle, flat geometrical figure with three straight sides. (*adj.*), *triangular*.
triceps, *muscle* with three points of attachment.
trough, shallow container for liquid to stand in.
trunk, (here) human or mammal's body without head, limbs and tail.
type, class or group considered to have some common qualities; *typical* (*adj.*), according to type.

udder, milk-*gland* of cattle from which milk flows through *teats*.
ultimate, last of all, final.
unfortunate, unlucky, unhappy (opp., *fortunate*).
unglazed, see *glaze*.
uniform, always the same, same throughout, not changing in form or character, not *varying*.
urine, waste liquid discharged from *bladder*.
utilize, use, make use of.

vacuum, space entirely *devoid* of matter, space from which air has been removed by air-pump, &c.
valve, movable part in vein or tube which controls the flow of liquid or gas.
vapour, *invisible moisture* in the air, gaseous form of a substance.
vary, change; make different, become different in degree or quality. (*adj.*), *variable*.
variety, class of things *varying* in certain qualities from the rest of the larger class (or *species*) that includes it.
vehicle, carriage, car, cart, or similar thing for carrying people or goods on land.
venous, of the veins.
ventilation, free movement of air in a house, etc.
verandah, open, roofed space along side of house.
vertical, upright.
vibrate, move continuously and rapidly to and fro. (*n.*), *vibration*.
victim, person or animal killed or hurt as the result of cruelty, disease, or accident, &c.
vigour, active strength or force.
vinegar, sour (acid) liquid got from *alcoholic* liquids and used for flavouring and preserving food.
visible, that can be seen, within range of sight (opp., *invisible*).
vision, act of seeing, process of seeing.
vital, concerned with or essential to life.
vomit, throw out from stomach through mouth.

whey, liquid left when milk forms *curds*.
whiskers, face-*bristles* of mammals.
whitewash (*n.*), mixture of powdered lime or chalk and water used for putting on walls, &c.; (*v.*), to put the mixture on to walls, &c., with a brush.
wilt (of plants), become soft, lose stiffness.
wire-gauze, *screen* made of fine wire.

yolk, yellow part of egg.

INDEX

(Where there are several references for one subject, the principal reference is in heavier type.)

abdomen, 4, 165, 244
abscess, 125
absorption, 10, 79, 82–83
accessory food substances, 50, 58
active immunity, 143–4
adaptation, 5
adrenal glands, 115, 246
adrenaline, 115
Aëdes, 176, 179
air, composition of, 263–7
air-conditioning, 279
air pressure, 13, 267–71
air-sacs, 14, 20
alcohol, effects of, 280
alimentary canal, 5, 7, 245–6
— system, 5, 87
alkalis, 49
alum, 216
amino-acids, 49, 82, 83, 252
Amoeba, 199
amoebic dysentery, 95
amylase, 81
anaemia, 158
animal fats, 48
— starch, 48
Anopheles, 165–8
anterior (anat.), 17
anthrax, 202
antibodies, 143
anti-infective vitamin, 61
antiseptics, 159, 161, 197, 206, 221
antitoxins, 143, 162, 206
anus, 10, 244
aorta, 18, 21, 152, 155, 247
appendicitis, 97–98
appendix (anat.), 97
aquatic animals, 3, 6
arch of foot, 35
arm-bones, 34
arterial blood, 21, 99
arteries, 16, 152
ascorbic acid, 66
asepsis, 207
Asiatic cholera, 97
assimilation, 79, 85
astigmatism, 133
Atebrin, 175
athletes' foot, 192
atmosphere, composition of, 266–7
atmospheric pressure, 13, 267–71
atoms, 46
auricle, 19, 151, 247
automatic actions, 40
— reflexes, 40–41
axis (skeletal), 33, 118
back-bone, 17, 31, 33
bacteria, 125, 141, 160, 180, 202, 203–4
bacterial diseases, 201–3
— dysentery, 95
— infection, 202
— spores, 162, 204
baking powder, 77
balance and position, 106, 111–12
balanced diets, 48, 55
ball-and-socket joints, 34, 119
barometer, 270
base (chem.), 48
bat (zoo.), 3
bathing, 190
BCG vaccination, 148–9
bed-bugs, 196–7
beet-sugar, 46
benign malaria, 171–6
beri-beri, 59, 60, 62–63
BHC (benzene hexachloride), 189
biceps muscle, 35
bi-focal lenses, 133
big brain, 43, 104, 248
bile, 9, 24, 81, 86, 254–5
bile-duct, 81, 245
bile-salts, 81, 254
bilharziasis, 185–6
birth, 3, 200
Biuret reaction, 252, 254
bladder, urinary, 27, 245
bladder-worms, 93
bleeding, 159–60
blood, 6, 16, 23–24
—, circulation of, 151–7
—, clotting of, 156
blood-capillaries, 16
blood-cells, 23–24
blood-corpuscles, 23–24
blood-groups, 159
blood-poisoning, 160–1, 206
blood-sucking insects, 165
blood-system, 151
blood-temperature, 274
blood-transfusion, 158–9
blood-vessels, 16
blood-volume, 23, 134
blubber, 38
body-building foods, 7, 51
body-cavities, 3, 245–6
body-circulation, 19, 21
body-heat, 48
body-lice, 195–6
body-regions, 4–5
body-systems, 30
body-temperature, 100

body-weight, 54
boil (*n.*), 161
bones, 5, 31, 57, 128–9
bone-fractures, 130
bone-structure, 31–32
boric acid, 134
bottling, 205
bowel, 81, 89
brain, 6, 31, 39, 42, 104, 248
breast-bone, 15, 33–34, 246
breathing, 10, 11–16, 27
breathing and burning, 263–6
bronchitis, 144
bruising, 66
buboes, 182
bubonic plague, 182
burning and breathing, 263–6

caecum, 98, 245
Calabar swellings, 179
calciferol, 67
calcium, 31, 57, 126, 129, 240
calorie, 52, 275
— chart, 234–5
calorific value, 55
calorimeter, 51
cane-sugar, 46
canine teeth, 122
canning food, 205
capillaries, 16, 19, 20
carbohydrates, 7, 46–48, 248–51
carbolic acid, 206, 209–10
carbon, 48
— dioxide, 6, 10, 16, 17, 26, 27, 139, 265–7
carnivores, 4, 121
carotene, 62
cartilage, 33, 119
casein, 70, 254
catalysts, 46, 79
cells, 16, 28–30
cellulose, 29, 48, 82
cement (dental), 122
Centigrade, 272
centipede bites, 164
central canal, 42, 104
central nervous system, 39, 42–44, 104
cerebellum, 43, 104
cerebrum, 43, 104
cess pools, 222
change of state, 275–6
cheese, 73, 254
chemical control, 114–16
— disinfectants, 209–10
— energy, 5, 10, 121
chemistry, 263
chest, 4
chest-cavity, 11, 34, 246
chest expansion, 137
chewing, 7, 79, 87, 126–7
chicken-pox, 146
chigger/chigoe, 197
child welfare, 228
chlorination of water, 216–17
chlorophyll, 5, 203
cholera, 94, 97
choroid, 108
cinchona bark, 168
circulation of blood, 19, 151–7
clinical thermometer, 274
clothing, 37, 45, 191
clotting of blood, 19, 156
coal-tar disinfectants, 209–10
cobra venom, 163
cochlea, 110
cold, sensation of, 114, 259
— storage, 205
cold-blooded animals, 100
colds, 149–50
collar-bone, 34
colloids, 85, 257
colon, 84, 245
common colds, 149–50
— salt, 57, 141
communicable diseases, 201
complete proteins, 56
complex carbohydrates, 47, 249–50
— sugars, 46, 248–9
composting, 220
compound fractures, 130
concave lenses, 132
condensed milk, 73
conscious control, 9, 35
conservation of energy, 51
constipation, 87
consumption, 146–9
control of infectious diseases, 227
converging lenses, 133
converted rice, 63
convex lenses, 133
cooking, 67, 76, 77
co-ordination, 104
cornea, 107
cow-pox, 145
crab-lice, 195
cramp (muscular), 141
cresol, 209–10
crucifixion, 158
crystalloids, 85, 257
Culex, 166, 178–80
culicine mosquitoes, 165–80
cultures, bacterial, 202
curative medicine, 1–2
Cyclops, 94

DDT, 173–4, 180, 183, 184, 189, 196
deficiency diseases, 59
dengue fever, 179
dental decay, 124
— — inspection, 127
dentine, 121
de-oxygenated blood, 19, 21
desiccation of foods, 205
destructors (refuse), 223–4
dew-point, 278
dextrin, 47, 250
dextrose, 47
dhobie itch, 192
dialysis, 84–85, 257
diaphragm, 3, 4, 9, 11, 245
diet, 54–77, 231–42
—, balanced, 55
—, mixed, 56
—, planning, 56, 69
diffusion, 7, 11, 21, 84–85, 256–7
digestion, 6, 7, 78, 79, 257
— in mouth, 80, 253
— in small intestine, 81–82
— in stomach, 80–81, 253–4
digestive glands, 79
— juices, 7, 9, 79–82
diphtheria, 142
disease, 1
diseases, infectious, 201
disinfectants, 206–8, 221

disinfecting agents, 207–10
disinfection, 206–10
disinfectors, steam, 207–8
disposal of excreta, 217–22
— of refuse, 223–4
dissection, 243–8
diverging lenses, 132
division of labour, 30
dorsal (anat.), 17
drainage, 225–6
dried milk, 73
droplet infection, 141
drugs, 280
ductless glands, 114
dumping refuse, 223–4
duodenum, 81
dust, 137–8, 267
dust-bins, 223
dysentery, 94–95

ear, 3
—, hygiene of, 135
—, structure of, 108
ear-ache, 135
ear-drum, 108
ear-wax, 135
earth-auger, 219
eel-worms, 90
egg-cells, 199–200
eggs as food, 73
elephantiasis, 178
emulsions, 255–6
enamel (dental), 122
encephalitis, 187
energy, 5, 10, 35, 45, 47, 48
energy-giving foods, 51
energy-output, 52–53
energy-requirements, 52, 232–6
energy-transformations, 5, 121
energy-values, 54
environment, 5
enzymes, 7, 46, 52, 79
epiglottis, 9, 15, 244, 247
erepsin, 82
ergosterol, 68, 129
espundia, 180
Eustachian tube, 108, 135
evaporated milk, 73
excreta, 217
— disposal of, 217–22
excretion, 26, 86
excretory organs, 26
exercise, 130, 155, 157
expired air, 259–62
external ear, 108
— respiration, 99
— stimulus, 39, 104
eye, hygiene of, 132
—, structure of, 106
eye-glass, 132

faeces, 10, 26, 84
Fahrenheit, 272
fainting, 19, 158
far-sight, 132
fatigue, 131
fat in body, 38, 84
— in food, 7, 48, 56, 251–2
fat-soluble vitamins, 60
fatty acids, 49, 81, 82
feeling, 43, 114, 258–9
Fehling's test, 248–9
femur, 34
fertilization, 200
fibrin, 156
fibrinogen, 156
fibula, 34
filaria-worms, 178–9
filarial blindness, 179
filariasis, 178
filter-passing germs, 203
filtering water-supplies, 216
filth diseases, 94, 210
fish as food, 58, 74
fish-liver oils, 61, 68, 129, 198
flea-borne typhus, 184
fleas, 184
flukes (zoo.), 185
fluorescein, 219
focussing, 107
food, 5, 45–86
—, classes of, 7, 45–50
—, functions of, 46
food-canal, 5, 245–6
food hygiene, 78
food-inspection, 226–7
food-preservation, 204
food-purity, 226–7
food-requirements, 5, 52, 232-42
food-tables, 55, 231–42
food-values, 231–42
food-yeast, 63
fore-brain, 42, 104
fore-limbs, 34
formaldehyde/formalin, 191, 209–10
fractures (bone), 130
fresh air, 138–40, 207
fructose, 47
fruit, 75
fungus diseases, 135, 191–2

gall-bladder, 81, 245
games, value of, 131
gaseous state, 275
gastric juice, 9, 80
germ theory of infectious diseases, 203
germicides, 161, 206
germs, 201–10
girdles (skeletal), 34
glottis, 9, 15, 244, 247
glucose, 47, 82, 83, 99, 248–9
glycerides, 49
glycerine/glycerol, 48, 81, 82
glycogen, 22, 48, 86
goitre, 58
grape-sugar, 47
grease-spot test, 251–2
green leafy vegetables, 75
green-stick fractures, 128
grey matter, 43
gristle, 33
growth, 10, 45
Guinea-worm, 94, 179
gullet, 7, 9, 245
gut, 10, 22

habits, 40
haemoglobin, 21, 24, 57
hair, 3, 37, 191
hair-muscles, 37
hair-pit, 37
handkerchief, use of, 141–2, 150
hard palate, 244
hard water, 49, 57

head-lice, 195
health, 1
—, public, 211–27
health education, 228
health services, 1
healthy carriers, 95–96, 142, 144
hearing, 108
heart, 16, 45, 151, 247
heart-beat, 18
heart-muscle, 121
heart-sac, 18, 152, 247
heat, 10, 35, 271–7
— of combustion, 51
heat-cramp, 140
heat-exhaustion, 140
heat-loss, 28, 101, 139
heat-sickness, 140
heat-stroke, 140
heat-units, 275
herbivores, 4, 121, 204
hibernation, 100
high-pressure steam disinfectors, 207–8
hind-brain, 42, 104
hind-limbs, 34
hinge-joints, 119
hip-girdle, 34
hip-joint, 34
hobbies, 132
honey, 47
hook-worms, 91–92
hormones, 114
house-flies, 94, 147
housing, 91, 224–6
humerus, 34
humidity, 139, 278–9
hydrocarbons, 48
hydrochloric acid, 33
hydrogen, 48
hydrolysis, 82, 249
hydrophobia, 164
hygrometry, 277–9

ill health, 1
immunity, 143, 144, 164, 202
—, active, 143
—, passive, 143
incinerators, 220, 223, 224
incisor teeth, 122
incomplete proteins, 56
indigestion, 77
infant death-rate, 228
— welfare, 228
infection, droplet, 141–2
infectious diseases, 201
inferior (anat.), 18
inflammation, 97
influenza, 150
ingestion, 78
inner ear, 108
inorganic matter, 33
insecticides, 172–4, 177
instinct, 116
intelligence, 44, 116, 117
internal ear, 108
— respiration, 99
— sense-organs, 112
intestinal diseases, 94
— juice, 10, 81–82
— worms, 89
intestine, large, 10
— small, 9
invert sugar, 47
involuntary actions, 9, 40
— muscles, 35, 120
iodine requirement, 51, 57
— test, 249–50
iris, 107
iron requirement, 50, 57, 240
itch (scabies), 192

jam, 47
Japanese river fever, 183–4
jaws, 33
Jenner, 145, 202
jigger, 197
joints, 118
jungle yellow fever, 176

kala-azar, 180
kidney-duct, 27, 246
kidneys, 6, 23, 27, 86, 246
kilo-calorie, 52, 275
Koch, 146, 202
krait, 163

lactase, 82, 249
lactation, 232–3
lacteals, 83
lactose, 47, 70, 248–9
large intestine, 10, 84
larva, 167–8
larynx, 15
latent heat, 102, 139, 276–7
laterite, 219
lather, 255
latrines, 91
—, bore-hole, 219
—, bucket, 219–20
—, pit, 217–18
Laveran, 169
laxatives, 89
leaf-green, 5
learning-process, 40
leg-bones, 34
legumes, 56, 74
leishmaniasis, 180
lenticels, 11
leprosy, 194–5
leptospirosis, 185
levers (bone), 5
lice, 184, 187, 195
ligaments, 33–35
ligature, 163
limb-girdles, 33
limbs, 5, 33, 118
lime, 209
lime-water, 261–2, 265
lipase, 81
liquid state, 275
Lister, 206
little brain, 43, 104, 248
liver, 9, 22, 23, 24, 83, 85–86, 245
loa-loa, 179
lockjaw, 161–2
long-sight, 132
louse-borne relapsing fever, 89
— — typhus, 184–5
low-pressure steam disinfectors, 207–9
lubrication of joints, 119
lung-circulation, 19–21, 151–6
lungs, 6, 11, 15, 247
lymph, 25, 83
lymph-glands, 24
lymph-vessels, 24

lymphatic system, 26
Lysol, 209–10

maggots, 201
malaria, 168–77
—, benign tertian, 171–6
—, malignant, 172
—, quartan, 172
malt sugar, 47
maltase, 82, 249
maltose, 47, 80, 248–9
mammals, characteristics of, 3
mammary glands, 3, 200, 244
Manson, 169
margarine, 68
marrow, bone, 24
measles, 143
medical services, 1
medulla, 42, 104
memory, 43
Mepacrine, 175
mesentery, 10, 245
metabolism, 78
mice, 184
microbes, 203
micro-organisms, 201
mid-brain, 104
middle ear, 108
milk, 70–72, 242
—, condensed, 73
—, dried, 73
—, evaporated, 73
— powder, 73
—, skimmed, 73
milk-sugar, 47, 70
milk-teeth, 123–4
mineral salts, 7, 46, 50, 57
mite, kedan, 183
mite-typhus, 183
mixed nerves, 40
molars, 123
molasses, 46, 76
molecules, 84
mosquitoes, 165–8
mosquito-control, 169, 173, 179
mosquito-nets, 174–5, 180
motor-nerves, 40, 42
moulds, 204–5, 267
mouth-breathing, 14
movement, 10, 31, 45, 112, 118
mucus, 95, 135, 150
mumps, 7
muscles, 5, 35, 119, 120, 247
muscular action, 35
— exercise, 130, 157
— work, 48
muzzling of dogs, 227

narcotics, 280
natural disinfecting-agents, 207
near sight, 132
neck, 4, 246
nerve-cells, 41–42
nerve-fibres, 41–42
nerves, 6, 39, 247
nervous impulses, 39
— system, 38, 104
niacin, 65
nicotinic acid, 65
night-blindness, 61
nitric acid test, 252
nitrogen, 41, 264
nose-breathing, 13-14
nostrils, 13, 136
nucleus, 29
nutrition, 45–86

oesophagus, 7
oil-glands, 37
oils and fats, 48, 251–2
omnivores, 4
Onchocerca, 179
optic nerve, 108
organic matter, 31
organisms, 31
organs, 30
organs of balance, 106
— of hearing, 109
— of sight, 106
— of smell, 113–14
— of taste, 113
— of touch, 114
oriental sore, 180
osmosis, 84
oval window, 109
ovaries, 199–200, 246
oviducts, 200, 246
oxidation, 6, 16, 35, 45, 48, 52, 266
oxygen, 6, 10, 16, 48, 139, 264
oxygenated blood, 21, 99
oxy-haemoglobin, 21, 99

pain, sensation of, 37–38, 114, 258
palate (hard/soft), 244
palm-oil, red, 62
palm-sugar, 46
Paludrine, 175–6
Pamaquin, 175
pancreas, 10, 245
pancreatic duct, 245
— juice, 9, 81
paralysis, 195
parasites, 203–4
—, blood, 165
—, skin, 191–8
parasitic worms, 89
paratyphoid fever, 96
parboiled rice, 64
parental care, 4
passive immunity, 143
Pasteur, 202
— treatment, 164
pasteurization of milk, 71, 205
pellagra, 65
penicillin, 206
penis, 200, 244
pepsin, 80, 253
pericardium, 16, 152
peristalsis, 9, 88
peritoneum, 10, 11, 89
peritonitis, 89
permanent teeth, 123–4
phenol, 206, 209–10
phosphorus, 31, 49, 57, 126, 129, 241
photosynthesis, 5, 267
physics, 263–79
pimples, 161
pituitary gland, 115
plague, bubonic, 180
—, pneumonic, 183
—, septicaemic, 183
plasma, 21, 23, 159
Plasmodium vivax, 172
— falciparum, 172

Plasmodium malariae, 172
Plasmoquine, 175
pleural cavity/sac, 11, 247
pneumonia, 144
pneumonic plague, 183
portal vein, 22, 83, 85, 245
position, sense of, 112
posterior (anat.), 17
posture, 104, 128-9
potassium permanganate 163
P-P vitamin, 60, 65
precipitate, 216
pre-molars, 122
preservation of food, 205
preventive medicine, 1-2
prickly heat, 191
primates (zoo.), 4
proboscis, 165
protective foods, 69-70
— responses, 40
proteins, 7, 22, 49, 241, 252
—, complete, 56
proteases, 79, 254
protoplasm, 29
ptyalin, 80, 251, 253
public health, 211-27
— — education, 211, 228-9
pulmonary artery/vein, 247
pulp (dental), 122
pulse, 18
pupa, 168
pupil (opt.), 106
pure food laws, 227
purgatives, 89, 98
purification of water, 205, 212-17
pus, 25, 66, 98, 160, 205-6
pylorus, 81
pyrogallol, 260-1

quarantine, 183, 227
quartan malaria, 172
quicklime, 209
Quinacrine, 175
quinine, 168

rabies, 164
radius (anat.), 34
rat-fleas, 180-1
rats, 180-5, 225
reasoning, 44, 117
rectum, 10, 84, 245
red cells/corpuscles, 23-24
Redi, 201
red palm-oil, 62, 198
reflex action/arc, 40-41
refrigeration, 205
refuse disposal, 223-4
registration of births and deaths, 228
— of infectious diseases 227
regulation of body-temperature, 28, 37, 100, 139
relapsing fevers, 187-8
relative humidity, 279
rennin, 81, 254
repair of tissues, 10, 45
reproduction, 6, 45, 199-200, 202
reproductive system, 199-200, 246
resonance, 110
respiration, 6, 10, 99, 259-62
respiratory system, hygiene of, 137
responses, 38, 40, 104
rest, 131, 148
retina, 106

riboflavin, 66
ribs, 4, 11, 33-34
rice conversion, 64
—, milling of, 63
—, parboiled, 64
—, polished, 63
rickets, 60, 67
rickettsiae, 183
ringworm, 191-2
rodents, 4
Ross, 169
roughage, 87-88
round window, 109
round-worms, 90

salads, 75
saliva, 7, 79, 80
salivary glands, 7, 247
salt, common, 57, 141
sandals, 192
sand-filters, 215-17
sandfleas, 197
sand-flies, 179-80
sand-fly fever, 179
sanitation, 91
saturation, 277-9
scabies, 192
Schick test, 143
schistosomes, 185
school medical service, 228
sclerotic, 108
scorpion stings, 164
scrotal sacs, 244
scrub-typhus, 183-4
scrubbing, 210
scurvy, 58, 66
sedimentation, 214-15
semicircular canals, 111
sensation, 39, 43
sense-organs, 4, 5, 6, 106, 132, 257-9
sensitivity, 104, 243
sensory nerves, 39, 42
sepsis, 207
septicaemic plague, 183
septic tank, 220-1
serum, 156
settling impurities, 214-15
sewage disposal, 206, 220-2
sewers, 222
shelter, 44, 101
shivering, 101
shock, 158
short sight, 132
shoulder-blade, 34
shoulder-girdle, 34
sickness, 1
sight, 106
simple reflex, 41
— sugars, 44, 47
sinus (nasal), 136
skeletal muscles, 19, 120
— system, hygiene of, 128-30
skeleton, 5, 31, 118, 128
skim milk, 73
skin, 37, 101
—, diseases of, 191-8
—, hygiene of, 190-8
skull, 31, 33
slaked lime, 209
sleep, 131-2
sleeping sickness, 187
sleepy sickness, 187

small intestine, 9, 245
smallpox, 145–6
smell, sense of, 114, 135–6, 257–8
smelling-patch, 114
smooth muscle, 120
snails, 186
snake-bite, 162–3
soap, 49, 83, 210
social services, 1
solid state, 275
sore throat, 149
soya-bean, 56, 75
Spallanzani, 202
spectacles, 107, 132
sperm-cells, 199–200
sperm-ducts, 246
sperms, 199–200
spider-bites, 164
spinal bulb, 42, 104
— cord, 31, 33, 39, 42, 104
— column, 33
— reflex, 41
spirochaetes, 187–8, 193
spitting, 147
spleen, 23, 24, 245
splints, 130
spores, resting, 162, 171, 204
spring-water, 212–14
sputum, 147
starch, 7, 76, 249
statistics, vital, 228
steam disinfectors, 207–8
Stegomyia, 176
sterilization, 197, 205, 207
sticking-plaster, 162
stimulus, 39, 104, 120, 243
stokers' cramp, 141
stomach, 7, 9, 80, 245
—, digestion in, 80–81, 253–4
stomates, 11
striped muscle, 120
subsoil drains, 173
subtertian malaria, 172
sucrase, 82, 249
sucrose, 46, 248–9
Sudan III test, 251–2
sugar, 7, 46, 76, 248–9
—, beet, 46
—, cane, 46, 248–9
—, fruit, 47
—, malt, 47
—, milk, 47, 70
—, palm, 46
sulpha-drugs, 206
sulphur in proteins, 49
sulphur dioxide, 209
sunlight, 207
superior (anat.), 18
surface tension, 81, 254–5
surgery, 206–7
sweat, 6, 37, 101, 140, 190, 277
sweat-ducts, 101
sweat-glands, 37
sweat-pores, 37, 101
swimmers' itch, 192
systems of organs, 30

tapeworms, 93
tartar (dental), 127
taste, sense of, 113, 135–6, 257–8
taste-buds, 113
tear-gland, 107
tears, 107, 134
teat, 244
teeth, 3, 57, 121–7
temperature measurement, 271
— regulation, 28, 37, 139, 100–3
temple (anat.), 18
temporary teeth, 123–4
tendons, 33, 35, 247
termites, 225
tertian malaria, 171–6
testes, 199–200, 241, 246
testis-sacs, 199
tetanus, 161–2
thermometers, 272–4
thiamine, 62
thigh-bone, 34
thorax, 4, 34, 244
thread-worms, 91
thyroid, 58, 115
tibia, 34
tick (zoo.), 183, 187, 189
tick-borne relapsing fever, 189
— — typhus, 184
tiger-mosquito, 176
tissue-fluid, 25, 155
tissue-respiration, 99
tissues, 30
tongue, 135
tooth-brush, 127
tooth-paste/powder, 127
touch, sensation of, 37, 114, 135–6, 258–9
touch-organs, 37
tourniquet, 160
town-planning, 226
toxins, 143, 162, 203, 206
toxin-antitoxin treatment, 143
toxoid treatment, 162
trachea, 14
trachoma, 134
transformation of energy, 5, 10
transfusion of blood, 158–9
transpiration in plants, 26, 277
transport in the body, 16, 23, 156
treacle, 46, 76
triceps muscle, 35
tropical ulcers, 197–8
trumpet, breathing, 168
trunk (anat.), 4, 244
trypanosomes, 187
trypanosomiasis, 187
trypsin, 81
tsetse flies, 187
tsutsugamushi disease, 183
tuberculin test, 148–9
tuberculosis, 146–9
typhoid fever, 94–96
typhus fevers, 183–5

udder, 71
ulcers, 197–8
ulna, 34
unconsciousness, 19
unstriped muscle, 120
urban yellow fever, 176–7
urea, 22, 27, 86
ureters, 27, 246
urine, 27, 86
uterus, 200, 246

vaccination, 145–6, 177, 227
vaccine, 146, 202
vaccinia, 145

vacuum, 270
vagina, 246
valves, 18, 20, 151–6
van Leeuwenhoek 201
vapour pressure, 277–9
vascular system, 6, 16
vegetable oils, 48
veins, 16, 155–6
vena cavae, 247
venous blood, 23
ventilation, 138–40, 210
ventral (anat.), 18
ventricle, 19, 151, 247
verandahs, 224–5
vertebrae, 33
vertebrates, 33
villi, 82
viper venom, 163
virus, 143, 145, 164, 176, 179, 184, 203
vision, 106
vital layer, 217
vital statistics, 228
vitamins, 46, 50, 58–70
vitamin A, 60, 61, 198, 237
— B_1, 60, 62, 66, 238
— B_2, 66
— C, 60, 66, 239
— D, 60, 67, 126, 198, 239
— E, 60
— K, 60
vitamin values of foods, 237–9
voice-box, 15
voice-cords, 15
voluntary actions, 40–41
— muscles, 35, 119, 120

warm-blooded animals, 3, 100
warmth, sensation of, 37–38, 114
waste-disposal, 217–24
water, 50
— as waste product, 27
—, purification of, 211–17
water-carriage sewerage systems, 222
water-soluble vitamins, 60
water supplies 205, 210–17
water-works, 214–17
water-vapour in atmosphere, 138, 266–7
wax in ears, 135
well-water, 212–14
wet- and dry-bulb thermometers, 279
whip-worms, 91
white cells/corpuscles, 23–26, 160
— matter, 43
whitewash, 209–10, 225
whooping-cough, 144
wind-pipe, 9, 11, 14, 15, 247
womb, 200, 246
work, 35, 48
worms, 89
wounds, 159

yaws, 193–4
yeast, 63, 68, 77
yellow fever, 176–8